

# **Annotated Literature Review: Health Benefits of Urban Greenspace**

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## EXECUTIVE SUMMARY

**Goal:** There is a significant body of research dating back many decades investigating the various health benefits of greenspace<sup>1</sup>, many of which can be categorized into measured and perceived mental, physical, or social benefits. In order to gain an understanding of this evidence base, a structured literature on health benefits of urban greenspace was conducted and relevant articles summarized.

**Findings:** There is a general consensus that urban greenspace influences human health in a positive manner, but in some cases, there was insufficient evidence to generalize about specific health outcomes including diabetes (Kondo et al., 2018), cancer (Kondo et al., 2018; Ekkel and Vries 2017) or birth outcomes (Kondo et al., 2018; Wolf et al., 2020; Fong et al., 2018; Ekkel and Vries 2017). Most original research studies utilized a cross-sectional study design (Kondo et al., 2018), with many researchers controlling for socio-economic status in their analyses (Wolf et al., 2020). In general, studies focused more on short-term health benefits of greenspace (e.g., improved blood pressure, stress reduction & cognitive performance) (Wolf et al., 2020). The lack of randomized control trials made it difficult to distinguish whether or not reported results were attributable to an intervention (i.e., introduction of physical activity) or to the urban greenspace itself, particularly in studies of short-term improvements in physical and psychological health (Saitta et al., 2019). Studies included in this review exhibited variation in sample size (e.g., eight to a combined 290+million) (Wolf et al., 2020; Twohig-Bennett et al., 2018), with the majority of studies having been conducted in Europe and the United States. The full range of the human life span has been represented in studies to-date: adults (71%) young adults (13%), children (13%) & older adults (3%) (Wolf et al., 2020). Measured outcomes have been shown to vary by geographical location and/or type of natural and built environment examined (Roberts et al., 2020). It is worth noting that few studies focused on health inequities or the impact or urban greenspace specifically on disadvantaged or vulnerable populations (Kondo et al., 2018).

Overall findings were positive associations between urban greenspace and attention, mood, and physical activity (Kondo et al., 2018) and negative associations between urban greenspace and mortality, short-term cardiovascular markers (e.g., heart rate, blood pressure) and violence (Kondo et al., 2018). Generally, exposure to greenspace resulted in improvement of overall well-being, reduced symptoms of depression, anxiety, attention deficit/hyperactivity disorder (Younan et al., 2016), and a boost in immune function (Capaldi et al., 2015; Rook 2013). Other findings of interest are presented below:

### Mental Health Benefits:



Exposure to urban greenspace can mitigate psychological stress by providing opportunity for physical activity, social interaction, and engendering cognitive and physiological responses associated with stress reduction and attention restoration, which may be pronounced for urban populations (Mennis et al., 2018; Jennings et al., 2016; Knecht 2004) more so for Black, indigenous, or people of color, which are subject to additional contextual societal (e.g., systemic racism) and environmental factors (e.g., proximity to sources of air pollution or major roadways) (Mennis et al., 2018).





Study participants were better able to perform a test of working memory after walking through an arboretum compared to those who walked on roads with heavy traffic and those who walked through the arboretum had 20% improvement in working memory (Hall and Knuth 2019).




A 10-20% reduction in perceived risk of poor mental health, depression and/or anxiety and intake of medication was found per interquartile range increase in average NDVI around homes, suggesting that there are substantial mental health benefits from nearby urban greenspace (Nieuwenhuijsen et al., 2017).


<sup>1</sup> It is important to note that while 'greenspace' may take on different meanings, the term has been used extensively to refer to areas of urban vegetation such as public and private parks, gardens, residential landscapes, urban forests or other municipal landscapes (Hall & Knuth 2019). Some studies focused on a specific type of green measure (e.g., tree canopy measure) or nature-immersive experience (e.g., outdoor education program intervention), but a common metric used to indicate amount of greenspace in a study area was normalized difference vegetation index NDVI (Kondo et al., 2018). Outcomes can and have been shown to vary by type of greenspace analyzed (MacBride-Stewart et al., 2016).


 Meta-analysis of studies showed that increased greenspace exposure was associated with decreased salivary cortisol, a marker of stress, with effect mean difference (EMD) -0.05 [95% confidence interval (CI) -0.07, 0.04] (Twohig-Bennett and Jones 2018).


 Physiological measures of stress (e.g., electromyography, skin conductance response, pulse transit time, cardiac response, partial thromboplastin time) indicated quicker and more complete recovery in a natural environment, even when measured over 10-minute period, and initial few minutes of recovery showed parasympathetic response which slows heart rate, increases intestinal and gland activity, and relaxes muscles in the gastrointestinal tract, while no such response was evident for urban settings (Berto 2014).

### Physical Health Benefits:


 Lower body mass index (BMI) among adults was observed in higher greenspace neighborhoods with more destinations for walking than in less green neighborhoods (Tsai et al., 2016) and proximity and access to urban greenspaces have been linked to healthier weights and lower BMIs in children (Chawla 2015; Hall and Knuth 2019), while perceived lack of greenspace and playground space among pre-school children have been independently associated with being overweight (Douglas et al., 2017).


 Increased greenspace exposure has been associated with heart rate [EMD -2.57 (95% CI -4.30, -0.83)], diastolic blood pressure [EMD -1.97 (95% CI -3.45, -0.19)], high-density lipoprotein (HDL) cholesterol [EMD -0.03 (95% CI -0.05, <-0.01)], low frequency heart rate variability (HRV) [EMD -0.06 (95% CI -0.08, -0.03)], increased high frequency HRV [EMD 91.87 (95% CI 50.92, 132.82)], and cardiovascular mortality [odds ratio (OR) 0.84 (95% CI 0.76, 0.93)] (Twohig-Bennett et al., 2018).


 Walk in nature have positive short-term effects on cardiovascular system and as measured in hypertensive patients, walks in nature decreased serum levels associated with high blood pressure, including endothelin-1, homocysteine, renin, angiotensin II type 1 receptor, and angiotensin II type 2 receptor, suggesting that walks in nature lower blood pressure in young, middle-aged, and older adults (Hall and Knuth 2019).

 Regular exposure to low concentrations of mixtures of natural compounds and toxins in natural environments confers pleotropic health benefits by inhibiting activities of interconnected cell-signaling systems (e.g., PI3K/Akt/mTORCI) and when overactive can lead to pathological processes resulting in cancer, diabetes, inflammation, immunosuppression, and/or neurodegenerative diseases (Nieuwenhuijsen et al., 2017).





### Social Health Benefits:

 Survey data revealed that across the United States, there is a significant positive relationship between attractive physical settings (e.g., trails, parks) and community satisfaction, encouraging social interactions across diverse populations, which can remedy decline of social relationships in urban areas (Jennings et al., 2016).

 Participants from multiple studies reported that accessible, usable parks enabled social interaction and development of social skills in addition to exposing people without disabilities to those with disability to foster community learning and improve tolerance and acceptance in society, while at the same time empowering social confidence of people with disabilities (Saitta et al., 2019).




 Urban greenery can help people develop a sense of community and neighborhood attachment, increase social contacts, and reduce feelings of social isolation (Nesbitt et al., 2017). Positive correlations between use of public urban greenspace and strength of neighborhood ties and sense of community have been reported, in addition to more deaths for older adult residents recorded in urban areas with low greenness (Douglas et al., 2017).

### Health Benefits of Access:

-  Disadvantaged communities, children, older people and people with mental health problems and pregnant women usually have less access to urban greenspace compared to more affluent populations but may be the greatest beneficiaries, suggesting that provision of access in a safe manner is important for reducing health inequities and buffer effects of some stressors (Kruize et al., 2019; Gascon et al., 2015).
-  Distance to destination, suitability of infrastructure (e.g., walking paths), and safety are very important factors motivating people to visit urban greenspaces (Kruize et al., 2019; Saitta et al., 2019; Hartig et al., 2014), and factors such as encountering busy roads may deter use of greenspace (Lachowycz and Jones 2013; Lee and Maheswaran 2011).
-  Across North American cities, underprivileged populations have disproportionately less access to vegetation including greenspace than affluent groups, with disparities more pronounced on public versus private land (Hall and Knuth 2019).
-  In the United States, typical standard suggested for ‘walkable’ is a destination within 0.25 miles or 400 meters at most (suggested by Sturm & Cohen 2014 in Ekkel & Vries 2017), but it has been shown that a distance of 100 to 300 meters (Ekkel and Vries 2017) is the threshold distance after which use of greenspace declines rapidly. Reported mental health measured using MHI-5 tool was better among residents having access to a park within 400 meters compared to those at 800+ meters (Ekkel and Vries 2017).

In addition to measured and perceived mental, physical, and social health benefits from urban greenspace, there are other areas of research that offer important findings on additional health benefits from urban greenspace. These include some less tangible and therefore harder to measure aspects (e.g., spirituality, feelings of vitality) as well as restoration from such practices as the Japanese art of shinrin-yoku (translated into English as ‘forest bathing’). A few notable findings are included below:

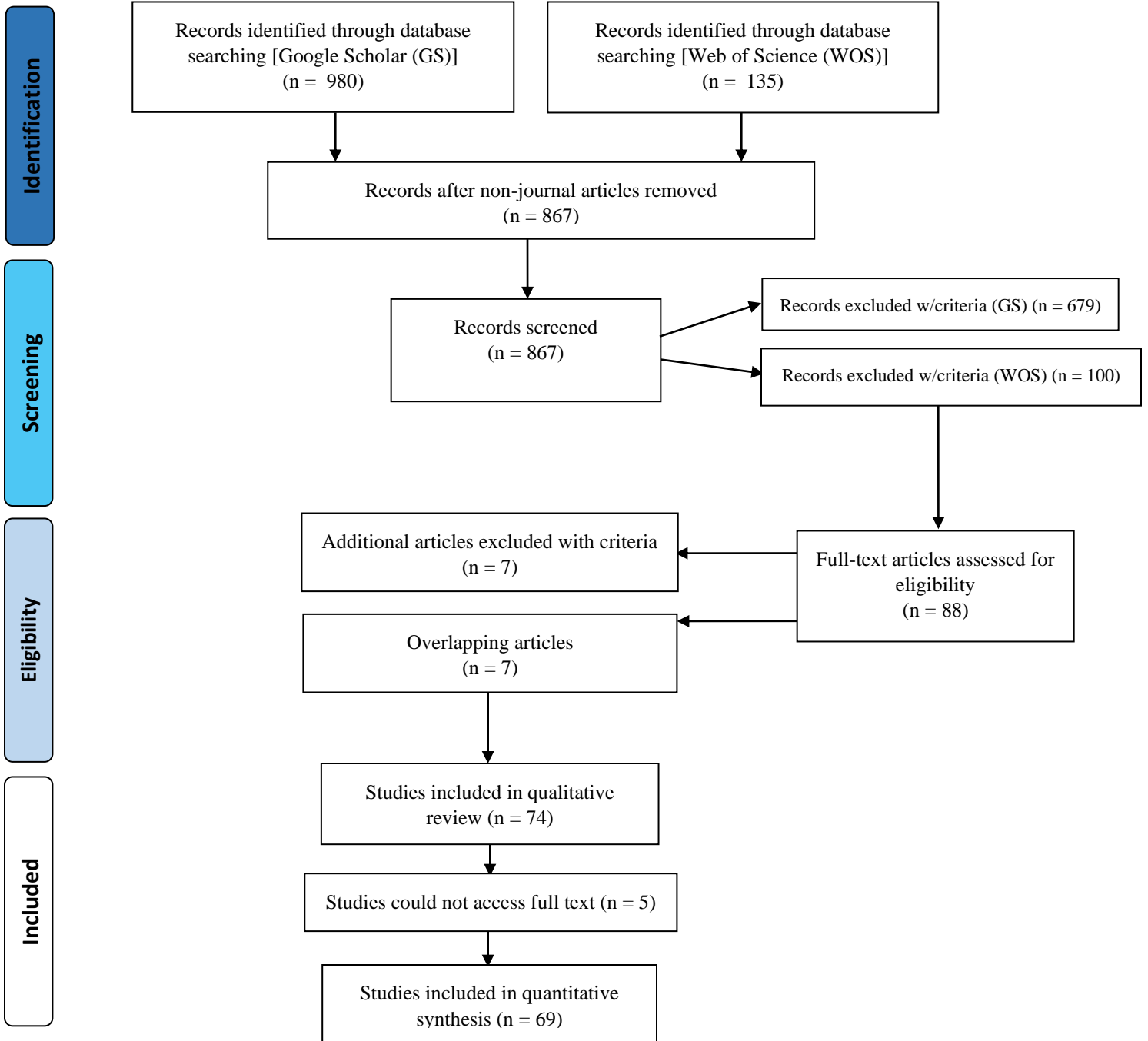
### Other Health Benefits:

-  Aspects of human-nature interaction important to well-being that are not well understood but may be important include sense of place, aesthetics and preference, spiritual beliefs (Dickinson and Hobbs 2017); these views could have an impact on the use of urban greenspace (Rakhshandehroo et al., 2015; Shanahan, Fuller et al., 2015).
-  Health benefits of greenspace found to be larger in some studies involving larger areas with more biodiversity compared to urban park environments (Roberts et al., 2019) and in studies including biodiversity as a measure of interest, it (biodiversity) has emerged as an important positive element for people using urban greenspaces (Carrus et al., 2015; Zhou and Rana 2012); variation in greenspace itself has important role in enhancing population health (Shanahan, Lin et al., 2015).
-  Functional magnetic resonance imaging (fMRI) scans showed that spending time in forest settings prompted the brain area activations related to involuntary attention and cognitive restoration and one study found that short 15-minute sessions of ‘forest bathing’ produced enhanced subjective feelings of vigor, recovery, and vitality (Wolf et al., 2020).

**Conclusion:** Urban greenspace is an important multi-faceted influence on the health of urban populations, with respect to mental, physical, social and other benefits. However, more research utilizing a randomized control trial approach is needed to best assess such health benefits, particularly with respect to specific types of greenspace or micro-environments (e.g., street tree canopy, arboreta, mixed use park). In addition, some research uncovered here has suggested that underrepresented and/or vulnerable social groups may benefit more from exposure and access to urban greenspaces, so further research in this area is needed to add to the current peer-reviewed literature evidence base. Accessibility to urban greenspace emerged as a recurring barrier for underrepresented populations, so attention to providing safe and inclusive accessible greenspace should be of priority for urban areas.

# LITERATURE REVIEW FLOW DIAGRAM

Keywords: "review urban green space health benefits"



## What is not included in this review:

- greenspace in indoor/office settings
- greenspace & long-term intervention programs
- biophilic architecture / nature imitation
- greenspace in imaginative capacity
- assessment of data quality
- greenspace in photos or video
- greenspace in form of community gardening
- greenspace views from residence or hospital
- negative effects of greenspace

**Mental Health Benefits of Urban Greenspace**





## Measured / Reported & Perceived Mental Health Benefits of Urban Greenspace

**Summary:** Forty-eight peer-reviewed articles contained information that reported a variety of findings on the relationship between mental health outcomes and different types of and access to urban greenspaces. Positive outcomes have been reported for stress (Kabisch et al., 2015; Capaldi et al., 2015; D’Alessandro et al., 2015; Kruize et al., 2019), short-term and working memory (Bratman et al., 2012; Jennings et al., 2016; Kondo et al., 2018), attention (Bratman et al., 2012; McCormick 2017), concentration (Rakhshandehroo et al., 2015; Douglas et al., 2017), cognitive function (Bratman et al., 2012), depressive symptoms (Beyer et al., 2014; Hall and Knuth 2019; Roberts et al., 2019), and anxiety (Hartig et al., 2014; Ekkel and Vries 2017), with some outcomes having a stronger relationship with the quality of greenery (Hartig et al., 2014). Data for these outcomes include both children and adults. There is also evidence for the potential for exposure to urban greenspace to contribute to decreased attention disorder hyperactivity disorder (ADHD) indications (Rakhshandehroo et al., 2015; Kabisch et al., 2017; Mennis et al., 2018; Kruize et al., 2019) and age-related behavioral maturation (Younan et al., 2016) in children. More diversity among research participants and more studies with randomized control study designs are needed in order to generalize results and strengthen the evidence base. Note: The type of article is indicated to the right of the reference (i.e., “ORIGINAL RESEARCH” or “REVIEW”).

### Gearin and Kahle (2006) ORIGINAL RESEARCH

- 16 high school seniors (n = 5 girls, n = 11 boys; n = 15 Hispanic, n = 1 Asian-American) & adults in Los Angeles, CA, USA; Focus group & survey
- Play in green neighborhood settings shown to result in post-activity reduction of Attention Deficit Disorder (ADD) behavior in children who suffer from it & **children who typically play in green play areas have less severe ADD symptoms** than those in less-green settings
- Other health benefits from green space include decreased mental fatigue (Kuo 2001) for public housing residents in greened developments

### Dean, Dooren, and Weinstein (2011) REVIEW

- Reviewed 1 article
- Fuller et al., (2007) conducted study of psychological benefits gained by people using greenspaces in city of Sheffield & demonstrated **positive association between species richness & psychological well-being**; degree of psychological benefit positively related to species richness of plants & to lesser extent birds, both taxa where perceived richness corresponded w/sampled richness; benefits did increase w/greenspace area but relationships w/plant & bird richness generally stronger; reflection, distinct identity and continuity with past increased w/greenspace area; **plant richness positively associated w/reflection & distinct identity**; bird richness positively related to continuity with past & attachment, number of habitat types positively associated w/reflection, distinct identity & continuity w/past

### Coon, Boddy, Stein, and ... (2011) REVIEW

- Reviewed 11 papers, 833 adults w/13 different outcome measures used to evaluate effects of exercise on mental well-being & four outcome measures used to assess attitude to exercise; all included studies measured effects of participating in physical activity on measures of mental well-being shortly following activity (most common mental well-being outcome some measure of an individual’s mood or feelings); most studies conducted on University campuses in United States
- All of studies examined reported effects on mental well-being immediately following cessation of single episode of exercise; duration of these effects is unclear, as are expected characteristics &



magnitude of effects following repeated exposure to outdoor activity & impact on adherence to long-term exercise initiatives

Bratman, Hamilton, and Daily (2012) REVIEW

- Reviewed papers using snowball sample starting with Stephen and Rachel Kaplan and Roger Ulrich, then compiled literature building off of these authors' work, then searched literature using articles referenced in Kaplan and Ulrich's work, then reference to "using computer search engines"; final "n" is not mentioned
- **Impacts of nature experience on human cognitive function and mental health** have been shown to occur **in measures of memory, attention, concentration, impulse inhibition, and mood cognitive function**
- Details different technologies that can be used to measure cognitive function
- Included studies that employ a particular set of tools and approaches (traditional psychology tests, surveys, and questionnaires) to quantify impacts of nature experience on specific aspects of cognitive function and/or mental health (attention, concentration, memory, impulse inhibition, stress, and mood). changes in attention and stress load can come from interaction with natural environments
- Attention restoration theory (ART) and stress reduction theory (SRT) both assert that contact with nature should induce positive affect, either through the replenishment of directed attention (and the relief and relaxation that this brings) or through the benefits of reduced stress thus, measurements of mood appear in studies that work within either of the theories' constructs
- Conscious preferences for landscape aesthetics may relate to restorative benefits of nature in complicated manner & individual's opinions about nature may impact the way in which natural environments ultimately impact mood & cognitive function
- Nature can have a restorative effect on the brain's ability to focus
- **Replenishment of our direct attentional capacities is the primary mechanism underlying effects of exposure to nature**

Zhou and Rana (2012) REVIEW

- Concept of "**biophilia**" suggests that **human cannot be separated from nature & contact w/nature is essence for psychological well-being**
- Kuo & Sullivan (2001) found that mental fatigue & aggression can be controlled & reduced in favorable environment
- Kellert & Wilson (1993) found that esthetic relish, such as **sense of tranquility & peace from green space can calm down people's rage & regulate emotion**

Keniger, Gaston, Irvine, and Fuller (2013) REVIEW

- Reviewed 57 peer-reviewed scientific literature prior to June 2011
- Berman et al. (2009) measured cognitive performance w/backwards digit span task, in which participants from Michigan, USA listen to sequence of numbers & repeat them in reverse order & results showed that **cognitive performance greater after students had walked through tree lined arboretum when compared w/busy city street & authors interpret this as evidence that restorative properties of nature can improve cognitive function**
- Taylor et al., (2001) found that in study of children diagnosed w/Attention Deficit Disorder (ADD) in the United States tested whether indirect interactions w/nature, such as exposure to nature during play, were related to attentional function, parents & carers of 96 children w/ADD completed questionnaire about child's attentional functioning after participating in leisure activities & **mean**

**post-activity attentional functioning ratings were significantly higher for green outdoor activities as opposed to those in other settings & severity of ADD symptoms was significantly lower after playing in natural areas outdoors**

- Interaction w/nature can increase self-esteem & mood, reduce anger & improve general psychological well-being w/positive effects on emotions & behavior & these interactions can have positive effects on cognitive function like academic performance & ability to perform mentally challenging tasks & interactions w/nature may have physical health benefits like stress reduction or reduced mortality rates as well as social, including facilitating social interaction or reducing crime & violence in urban areas

Berto (2014) REVIEW

- Mental fatigue gives higher preference for natural over urban environment & nature is especially conducive to our involuntary attention engagement, on contrary built content captures attention dramatically, requiring attention to be overcome
- Wadson et al., (1963) found evidence that exposure to natural environments had direct influence on urine & blood levels of cortisol
- Strife & Downey (2009) found that children playing in highly natural school playgrounds showed fewer attention & concentration problems & improved cognitive & physical functioning than children playing in less natural school playgrounds
- Exposure to natural environments produce positive mood changes, actually exposure to natural stimuli can mediate negative effect of stress reducing negative mood state & at same time enhancing positive emotions & in particular natural settings have restorative influences on 3 affective dimensions: 1) positive affects, anger/aggression & fear; 2) mental/attentional fatigue manifests itself in negative emotions, irritability, impulsiveness, impatience, reduced tolerance for frustration, insensitivity to interpersonal cues, decrease altruistic behaviors, reduced performance, increased likelihood of taking risks & generally speaking in reduced competence &/or decreased effectiveness in functioning & 3) restricted access to green spaces may increase people's vulnerability to impact of stressful life events & environmental stressors affecting physical & psychological well-being & higher accessibility to park/forest-like area correlates w/higher happiness, lower stress, anger, depression & tension, improved mood & concentration
- Using paradigm in which stressed individuals were exposed to simulations of either natural or urban environments, Ulrich (1961) encompassed range of restorative effects of natural environments on human beings w/research showing different rates of recovery from stress depending upon type of environmental exposure & **physiological measures of stress (e.g., electromyography, skin conductance response, pulse transit time, cardiac response, partial thromboplastin time) indicated quicker & more complete recovery in natural environment exposure conditions**, even when recovery was measured over 10-minute period only & in initial minutes of recovery, parasympathetic component response recorded to natural environments, whereas there was no evidence of parasympathetic involvement in response to urban settings

Haluzka, Schonbauer, and Cervinka (2014) REVIEW

- Reviewed 17 studies mostly from Japan; no confounders listed but indicate that the following aspects of studies may have decreased the quality of studies: factors influencing heterogeneity of outcomes could include low assessment quality, in particular due to participant factors (socio-demographic or disease status), outdoor settings (weather features), type of intervention (components, intensity, timing), and appropriateness of the respective control group and statistical power (small or inadequate

sample sizes); 20 different physiological parameters reflecting effects of exposure to outdoor nature were derived from the 17 articles reviewed; most studies were conducted on Japanese male students

- Short-term restorative effects of outdoor nature could be found for almost all measured physiological parameters

#### A. Dzhambov and D. Dimitrova (2014); (A. M. Dzhambov & D. D. Dimitrova, 2014) REVIEW

- Reviewed 24 studies were read in full and reduced to 5 studies included in review
- Vegetation influences both physical properties of sounds and ways in which people perceive, evaluate and respond to sound in different urban settings

#### Beyer, Kaltenbach, Szabo, Bogar, and ... (2014) ORIGINAL RESEARCH

- Study of 2,479 individuals nested in 229 Wisconsin Census Block Groups (2008–2009, 2010 and 2011 cohorts of SHOW, ages 21-74 years); used Normalized Difference Vegetation Index (NDVI); used Survey of the Health of Wisconsin (SHOW) database, an ongoing survey established in 2008, that includes information collected through interviews, physical exams & biospecimens from representative sample of Wisconsin residents
- Adjusted for all individual level (age, gender, race and ethnicity, education, income, marital status, insurance status) & neighborhood level (urbanicity/rurality, population density, education, instability, unemployment, poverty, housing tenure, percent African American, median household income) factors; also models adjusted for length of residence of respondent in neighborhood environment measured
- Outcome measures comprise 3 scales of 42-item Depression Anxiety and Stress Scales (DASS) instrument indicating symptomology for depression (self-disparaging; dispirited, gloomy, blue; convinced life has no meaning or value; pessimistic about future; unable to experience enjoyment or satisfaction; unable to become interested or involved), anxiety (apprehensive, panicky; trembly, shaky; aware of dryness of mouth, breathing difficulties, pounding of heart, sweatiness of palms; worried about performance and possible loss of control) and stress (over-aroused, tense; unable to relax; touchy, easily upset; irritable; easily startled; nervy, jumpy, fidgety; intolerant of interruption or delay)
- Results indicate that **difference in depressive symptoms between individual living in environment w/no tree canopy & environment w/100% tree canopy is larger than difference in symptoms associated w/individual who is uninsured compared to individual w/private insurance**; those from lower income brackets & w/out private health insurance experience greater anxiety, stress & depression, supporting notion that **low socioeconomic populations could benefit more from increased exposure to green space**; here appears younger adults may currently experience greater need to receive mental health benefits conferred by greener environments
- Recent research has linked green space directly to biomarkers of stress & attention—diurnal variation of salivary cortisol & brain waves as measured by portable electroencephalogram (EEG) devices — suggesting biologically plausible link between exposure to green space & reduction of stress & mental fatigue

#### Hartig, Mitchell, de Vries, and Frumkin (2014) REVIEW

- Reviewed 59 articles (only "review" articles)
- Sugiyama et al., (2008) found **perceived social coherence & local social interaction to be associated with perceived greenness of the neighborhood**

- De Vries et al., (2013) found an association between streetscape greenery and perceived social cohesion at the neighborhood scale, both for the quantity; **reductions in self-reported anger, fatigue, anxiety & sadness & increase in feelings of energy with exposure to nature & even more strongly for quality of greenery**
- Some research does suggest that restorative childhood contact with nature can cumulatively provide benefits with far-reaching developmental significance & that contact with nature may for example improve attentional function in children with ADD

#### Christian et al. (2015) REVIEW

- Reviewed 32 articles mostly conducted in USA, Australia & Europe w/over two thirds (69%) examining behaviors (e.g., outdoor play & physical activity) through which children develop social-emotional competence, language & communication skills, rather than domains of early child development per se
- Some evidence to suggest that green spaces may be important for young children's cognitive (Wells, 2000, Kuo and Taylor, 2004) & motor (Fjortoft, 2004, Fjortoft and Sageie, 2000, Fjortoft, 2001) development
- This review highlights that neighborhood physical environment may be more important for some domains of early child health & development (e.g., physical health & well-being & social competence) than others (e.g., language & communication skills) & that children's play in natural environments more diverse, imaginative & creative than children's play in other settings (Strife and Downey, 2009)

#### Kabisch (2015) REVIEW

- Reviewed 219 articles published in English between 1 January 2000 & 1 October 2013; 40% of all studies applied questionnaire surveys which included interviews, focus groups, or observations applied followed by analyses using a geographic information system (GIS)
- Hansmann et al. (2007) showed that people felt more well-balanced & reported significantly lower stress level after arriving at park than before arrival
- Aspinall et al., (2013) used mobile EEG system outdoors & EEG-based emotion recognition software for functional brain imaging to record any stress reduction as people walked into urban green spaces & identified that transition from urban shopping street to green space related to reductions in arousal, frustration & engagement & to increase in meditation
- Ward Thompson et al., (2012) measured salivary cortisol to assess different stress levels related to green space use & found that **green space & physical activity significantly related to cortisol slopes that lead to lower stress level**

#### Gascon, Triguero-Mas, Martínez, and ... (2015) REVIEW

- Reviewed 28 articles; most of studies considered to be of fair quality & only two of poor quality; Most studies surrounding greenness measured as % of green space in specific buffer [from 300 meters (m) to 3 kilometers (km)] or at census area unit level (CAU) using a land-cover map & 7 studies used NDVI as indicator of surrounding greenness located in buffers of 100 to 800 m; half of studies including adults used General Health Questionnaire (GHQ) (n=10), the Mental Health Inventory (MHI) (n=1) or the Short Form health survey (SF) (n=2) to evaluate general mental health
- Limited evidence for causal relationship between surrounding greenness & mental health in adults, whereas evidence inadequate in children; evidence also inadequate for other exposures evaluated (access to green spaces, quality of green spaces & blue spaces) in both adults & children

- Annderstedt et al., (2012) found that access to serene & spacious green spaces associated w/reduced risk of poor mental health (measured with GHQ) in women who were physically active

Cohen-Cline, Turkheimer, and ... (2015) ORIGINAL RESEARCH

- 4,338 monozygotic (MZ) & dizygotic (DZ) twins from Washington, USA Community-based University of Washington Twin Registry; used Normalized Difference Vegetation Index for measure of greenness; used 2-item Patient Health Questionnaire (PHQ), perceived stress scale (PSS) & brief symptom inventory for participants; adjusted for income, physical activity, neighborhood deprivation, population density
- **Greater access to green space in home neighborhood associated with less depression**, even when controlling for genetic and shared environmental confounders & less evidence for effects on stress or anxiety
- When treating twins as individuals (& not members of twin pair) green space significantly inversely associated w/each mental health outcome & association w/depression remained significant in within-pair MZ univariate & adjusted models
- MZ within-pair effect in unadjusted model for depression suggests that, on average, people who live in or around dense vegetation have 0.44 (on scale of 0-9 for PHQ-2) lower depression score than those who live in location without any access to green space

Capaldi, Passmore, and ... (2015) REVIEW

- Appears that **having access to nature near one's home can provide buffer against mental distress & promote sense of satisfaction w/one's life**; nature connectedness has also been linked w/psychological resilience, which is key in managing stress & maintaining positive mental health; outdoor education & experiential learning literature describes similar benefits of wilderness & nature immersion experiences on autonomy & other measures of psychological well-being like personal growth, self-esteem, self-regulation & social competency
- Compared to built environments, nature can decrease arousal & perceived stress levels & promote psychophysiological stress recovery (e.g., decrease blood pressure) after attentional abilities are fatigued; moreover, **access to nearby nature can buffer against stress**

Webster (2015) REVIEW

- Limited exposure to nature led to nature deficit disorder
- Gardening is therapeutic, of spiritual importance, and contributes to stress reduction

Cassarino and Setti (2015) REVIEW

- No systematic method mentioned
- Identifies many potential confounders including education or occupation
- When examining rural vs. urban environments air pollution, diet, vitamin D deficiency etc. are confounders & neighborhood, socioeconomic status (SES), noise
- Cognitive aging
- Geographical environment, defined in terms of rurality versus urbanization, presence of green, environmental layout and complexity, levels of traffic and noise, can act as a source of brain training and possibly contribute to cognitive resilience in older age
- Association between environmental characteristics and cognition, with a particular emphasis on physical or more broadly geographical aspects of the environment that influence perceptual and cognitive processing

#### Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using the key words “child\*,” “youth,” “young people,” or “adolescents” in combination with “health” or “well-being” and “natural environment,” “green space,” or “parks”; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); ethnographic work on children in nature in the 1970s and later years was gathered through the author’s participation in the development of this field
- Air pollution, noise, temperature were confounders noted in the section on physical health
- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety
- Because psychological well-being is subjective experience as well as an expert diagnosis, levels of greenery have been related to children’s self-assessments, parent’s perceptions of their children’s condition, and professional diagnoses; All of these measures indicate that access to nature is a protective factor
- Contact with nature can reduce symptoms of ADD and attention deficit and hyperactivity disorder (ADHD) in children
- **Natural areas provide for more imaginative, constructive, sensory & socially cooperative** play than asphalt, flat expanses of lawn, or built play equipment

#### D'Alessandro et al. (2015) REVIEW

- Results section indicates search but then different article cited; number of citations do not match up with references: “A «web of knowledge» search with just two terms, «green space and health», yielded 2 hits for 1990-1999, 34 for 2000-2009, and 45 from 2010 to June 2013; in the same paper; authors performed a «review of reviews» on the topic until April 2013, involving 56 relevant reviews 2009, and 45 from 2010 to June 2013”
- Living near green space reduced stress

#### Rakhshandehroo, Mohdyusof, Tahir, and ... (2015) REVIEW

- Nature & green spaces make positive impact on public mental well-being in ways including: mental health (Van Dillen, de Vries, Groenewegen & Spreeuwenberg, 2012), psychological well-being (Abkar, Kamal, Mariapan, Maulan, & Sheybanic, 2010; Stodolska, Shinew, Acevedo, & Izenstark, 2011), enhanced concentration capacity (Tsunetsugu et al., 2013), decreased Attention Disorder Hyperactivity Disorder (ADHD) indications (Kaplan & Kaplan, 1989; Taylor & Kuo, 2009), post-disaster recovery (Rung, Broyles, Mowen, Gustat & Sothern, 2011; Okvat & Zautra, 2014) and self-reported general health, feelings of pleasure, enjoyment, relaxation, comfort & calmness (Stigsdotter et al., 2010; Schipperijn, Stigsdotter, Randrup & Troelsen, 2010) & tranquility (Watts, Miah & Pheasant, 2013)

#### Carrus, Scopelliti, Laforteza, and ... (2015) ORIGINAL RESEARCH

- Study of four Italian medium-to-large size cities: Bari, Florence, Rome & Padua; Questionnaire including measures of length & frequency of visits, perceived restorativeness & self-reported benefits of visit to green spaces; questionnaire had four parts: 1) open-ended, multiple-choice & Likert-type scale questions on setting experience (length and frequency of visits, crowding), main activity performed (socialization, walking, contemplation, or physical activity) & socio-demographic data, 2) eight items taken from Italian version of Perceived Restorativeness Scale (PRS) measuring restorative

properties of settings on 5-step Likert scale (scores range from 0 to 4; Cronbach's alpha value is 0.79, indicating good level of internal consistency & reliability), plus single item measuring preference for settings i.e., “I like this place”; 3) six items derived from Laforteza et al. (2009) measuring psychological & physical benefits experienced in environment on 5-step scale (e.g., “Do you feel psychological benefits while visiting this place?”; “Do you feel physical benefits while visiting this place?”; “Overall, how much visiting this place makes you feel better than before?”; scores range from 0 to 4); study population 569 residents (convenience sample); 4 different types of green areas selected for study varying in level of biodiversity richness (low vs. high) & location (urban vs. peri-urban) according to 2 × 2 factorial design: 1) urban square with trees (urban location, low biodiversity), 2) urban park (urban location, high biodiversity), 3) pinewood forest plantation (peri-urban location, low biodiversity), 4) peri-urban protected reserve (peri-urban location, high biodiversity)

- **Positive role of biodiversity upon perceived restorative properties & self-reported benefits for urban & peri-urban green spaces**
- Previous research revealed amount of exposure to nature (e.g., frequency & length of visits to urban parks), promotes self-reported benefits & well-being
- High level of biodiversity more strongly linked to benefits & well-being & to perceived restorativeness in case of urban green areas, compared to peri-urban green areas; self-reported benefits & well-being significantly correlated w/length of visit to green areas ( $r = 0.15$ ;  $p = 0.000$ ;  $n = 566$ ), biodiversity level ( $r = 0.22$ ;  $p = 0.000$ ;  $n = 569$ ) & perceived restorativeness ( $r = 0.68$ ;  $p = .000$ ;  $n = 568$ ) & 2 main predictors (i.e., length of visit & level of biodiversity) were independent of each other ( $r = 0.08$ ;  $p = 0.06$ ;  $n = 566$ ), suggesting possible mediation process where both **length of visit & level of biodiversity influence benefits & well-being through perceived restorativeness**; modeling showed length of visit to green areas positively predicted self-reported benefits & well-being through perceived restorativeness

Jennings, Larson, and Yun (2016) REVIEW

- Natural settings in cities can buffer stress or risk of depression across the United States
- Studies linking benefits from green spaces w/aspects of educational achievement & cognitive functioning
- Berman et al., (2012) conducted study in Michigan & **found interactions in nature can positively affect mood & short term memory of depressed individuals nearly five times as much as non-depressed individuals**
- Many studies demonstrated **relationship between exposure to natural environment & subjective well-being** (e.g., happiness), important because emotional well-being (e.g., perceived life satisfaction), psychological well-being (e.g., self-acceptance & capacity for personal growth), & social well-being (e.g., sense of community) can be **key indicators of mental health**, via Centers of Disease Control and Prevention

Eisenman (2016) REVIEW

- Beneficial links between green space and a range of human health outcomes including, but not limited to: self-reported physical and mental health, perceived general health
- In cities, psychological benefits are likely derived in two ways: 1) by **providing a visual and auditory barrier to challenging environmental conditions, green spaces may diminish people’s apprehension of potential stressors** & 2) **green space can help people to restore adaptive resources**; this restorative quality does not merely depend on the absence of stressors, which can motivate people to escape the social and environmental pressure of cities through recreation in more

natural settings but can also be defined in positive terms, wherein nature contact yields beneficial outcomes in and of itself

- Two principal theories may explain how restoration can occur once a person has achieved perceptual distance from stress-inducing influences: stress reduction theory (SRT) and attention restoration theory (ART)

#### Younan et al. (2016) ORIGINAL RESEARCH

- Study of 1,287 individuals (of 640 families) including 276 MZ & 364 DZ twin pairs in Los Angeles, CA, USA; used Normalized Difference Vegetation Index (NDVI); participants part of Risk Factors for Antisocial Behavior twin study based at University of Southern California; a prospective study of interplay of genetic, environmental, social & biological factors on development of antisocial behavior from childhood to early adulthood; aggressive behavior assessed using Child Behavior Checklist (CBCL/6-18)
- Crude analyses showed **aggressive behaviors decreased w/increasing exposure to short-term (1-, 3- & 6-months) & 3-year average NDVI in 1000 m** before CBCL assessment; adjustment for sociodemographic factors, neighborhood quality & 6-month average temperature resulted in increase in strength of short-term effect estimates for NDVI averaged in 1000 m buffer; adjusted analyses suggested consistent pattern of decreased aggression associated w/increasing greenspace w/in 1000 m buffer, w/both **short-term & long-term beneficial effects equivalent to 1.9 to 2.2 years & 2.1 to 2.5 years of age-related behavioral maturation**, respectively; effect estimates not sensitive to further adjustment for proximity to freeways or roads, traffic density in 150- or 300 m area, or maternal smoking during pregnancy; living w/in close proximity to park, golf course, or field, in comparison to residing in location surrounded by other housing, shopping centers, or freeways, was equivalent to having increased NDVI associated with 0.36 to 0.41 reduction in aggressive behavior scores

#### MacBride-Stewart, Gong, and Antell (2016) REVIEW

- Women report preferring to exercise in natural environments, such as the park, instead of the city streets or inside gym because of its perceived aesthetic and therapeutic qualities

#### Kabisch, Bosch, and Laforteza (2017) REVIEW

- Reviewed 27 articles & restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Previous research showed that children's cognitive, emotional & motor development may be associated w/exposure to nature (Amoly et al., 2014, Dadvand et al., 2015) & these developmental effects of nature exposure may explain why many studies have suggested that nature exposure reduces symptoms in children suffering from attention deficit hyperactivity disorder (ADHD)
- Younan et al., (2016) showed exposure to green space w/in 1000 m surrounding residences associated w/reduced aggressive behaviors in children 9–18 years of age
- **Interactions w/green spaces have positive effect in alleviating symptoms of ADHD & improving concentration capacity** (Taylor et al., 2001, Faber Taylor and Kuo, 2009)
- Ode Sang et al., (2016) assessed self-rated health perceptions & mental health finding that higher perceived naturalness generated more activities, higher aesthetic values & self-reported well-being in residents living close to urban green spaces & that **elderly residents participated in greater number of nature-related activities than younger residents & reported improved mental well-being associated w/urban green**



- Dzhambov and Dimitrova (2014) found negative correlation between actual time & frequency of interacting w/park & health anxiety among elderly people

L Nesbitt, Hotte, Barron, Cowan, and ... (2017) REVIEW

- Reviewed 38 articles focused on North America that examined the services of mixed vegetation (i.e., multiple or unspecified types of vegetation), 31 studies that examined the services of trees, and 43 studies that examined the services of green spaces
- Patients in hospital rooms overlooking green, natural areas had a recovery rate 8.5% faster and used fewer painkillers than patients without such views (Ulrich, 1986); Potential cost savings represented by these reduced recovery times were estimated at USD\$93 million annually in the United States healthcare context (Browning et al., 2012)
- Seeing and being in the presence of trees can reduce stress, improve emotional health, and enhance quality of life
- Urban greenery can improve ADHD
- In the Netherlands, depression rates found to be 1.33 times higher in areas with limited green space than in areas with abundant green space (Groenewegen et al., 2012)
- Taylor et al. (2015) found that an additional tree per kilometer of street in London, UK, correlated with a decrease of 1.18 anti-depressant prescriptions per 1,000 people

O Douglas, M Lennon, and M Scott (2017) REVIEW

- Sugiyama et al., (2008) collected survey data relating to physical & mental health scores, perceived neighborhood greenness, walking for recreation & for transport, social coherence; local social interaction & socio-demographic variables & analysis revealed that after adjusting for socio-demographic variables, those who perceived their neighborhood as highly green had 1.37 & 1.60 times higher odds of better physical & mental health, respectively, compared w/those who perceived lowest greenness
- Presence of more green space linked w/healthier cortisol profiles while **less green space typical of deprived neighborhoods shown to produce higher stress & flattened cortisol profiles in adults, indicating poorer capacity to recover from stress**
- **Access to green space associated w/reduced risk of stress, propensity to psychiatric morbidity, psychological distress, depressive symptoms, clinical anxiety & depression prevalence & mood disorder treatment in adults**
- Examination of impacts of environments on attention in **children w/Attention Deficit Hyperactivity Disorder (ADHD)**, Taylor and Kuo (2009) found that subjects **concentrated better after walk in park** than after downtown walk or walk in neighborhood, concluding that **“doses of nature” might serve as safe, inexpensive, widely accessible way to manage ADHD symptoms**
- Prospective study of 7–10 years old primary school children, Dadvand et al., (2015) observed improved cognitive development in children exposed to green surroundings, controlling for factors such as socio-demographics & pollution

E. D. Ekkel and de Vries (2017) REVIEW

- Nutsford et al. (2013) studied association between distance to nearest usable green space w/minimum size of 500 m<sup>2</sup> & mental health & observed **decreased distance to usable green space** of that size **associated w/decreased anxiety/mood disorder treatment** counts in urban environment

- Krekel, Kolbe & Wüstemann (2016) calculated distance to nearest green space w/minimum size of 0.25 ha (2500 m<sup>2</sup>) & observed **positive association between access to green urban areas & life satisfaction** but not possible to recommend quantifiable cut-off point based on these studies
- Reklaitiene et al. (2014) studied relationship between green space proximity (<300 m, 300–999 m, >1 km linear distance) & depressive symptoms & perceived general health & results confirmed negative association between residential proximity (living close to park vs. >300 m) & depressive symptoms as well as poor & very poor perceived general health but for women only
- Sturm & Cohen (2014) **reported mental health (MHI-5) better among residents having access to park w/in 400 m & decreased significantly over next distances: 800 m, 1600 m, 3200 m**
- Stigsdotter et al. (2010) reported poorer health, higher odds of experiencing stress & health-related quality of life for people living >1 km away from nearest green space compared to respondents living <300 m from nearest green space
- In Public Open Space (POS) studies, high quality & attractive POS positively associated w/psychosocial distress (Francis et al., 2012) & walking activity (Giles-Corti et al., 2005)

#### McCormick (2017) REVIEW

- Reviewed 12 articles
- Overall well-being and psychological distress were measured using the Strengths and Difficulties Questionnaire (SDQ) in three studies finding that high quality and quantity green space was associated with better child well-being (Feng & Astell-Burt, 2017), less total difficulties, emotional symptoms, and peer relationship problems (Amoly et al., 2014), and a > 20 min walk to green space was associated with worse mental and overall health (Aggio et al., 2015)
- **Children performed better on attention tasks and spatial working memory after a walk in nature** compared to a walk in an urban landscape (Schutte, Turquati, & Beattie, 2017)
- Green outdoor settings were found to reduce symptoms of inattention and hyperactivity in children diagnosed with ADHD (Kuo & Faber Taylor, 2004), and inverse relationship was found between residential greenness and ADHD/DSM-IV total and inattention scores (Amoly et al., 2014)

#### van den Bosch and Sang (2017) REVIEW

- Reviewed 13 total peer-reviewed articles written in English found in April 2016 ("only 3 of those were retrieved if including health in the search terms")
- Conclude that there is strong, consistent evidence for correlation between stress & cardiovascular disease (CVD)-mortality (Ippoliti et al., 2013, Lu et al., 2013) & moderate to strong evidence for stress as risk factor for all-cause mortality, mental disorders & reduced birth weight or preterm birth (Staufenbiel et al., 2013, Gallo et al., 2014, McEwen, 2012, Ding et al., 2014)

#### Nieuwenhuijsen, Khreis, Triguero-Mas, Gascon, and Dadvand (2017) REVIEW

- More consistent & promising pathways are stress reduction & restoration; **stress reduction theory** suggests that natural environments promote recovery from stress & help lessen states of arousal & negative thoughts through psychophysiological pathways; natural elements w/characteristics (e.g., level of ground surface, spatial openness, curving sightlines, presence of water) may induce recovery from any form of stress, even mild short-term stress, via an unconscious & innate response; **attention restoration theory** suggests that nature can replenish directed attention fatigue; natural environments abound w/"soft fascinations" that a person can reflect upon in "effortless attention," such as clouds moving across sky, leaves rustling in breeze or water bubbling over rocks in stream

- Ulrich et al., (1991 & 1991b) found that patients who underwent gall bladder operation & had view from window w/trees recovered faster & used fewer potent analgesics than patients with view of brick building wall
- Japanese have developed practice called "shinrin yoku" or forest bathing to relieve stress; electroencephalography, in which signals are translated & classified in different emotional states, showed different responses for volunteers walking around in different neighborhoods (urban shopping streets, green space & busy commercial districts); volunteers showed **lower frustration, engagement & arousal & higher meditation when moving into green space zones**
- Bratman et al., (2015) showed that after walk in nature, subjects showed **reduced rumination, as measured by questionnaire & reduced blood perfusion in subgenual prefrontal cortex** compared with walk in urban area; **reduced activity in subgenual prefrontal cortex has been associated w/improved symptoms in people w/depression & regulation of cortisol levels**, which is related to reduced stress
- Cross-sectional study by Triguero-Mas et al., (2015) found **10% - 20% reduction in perceived risk of poor mental health, perceived depression and/or anxiety & intake of tranquilizers or sedatives, antidepressants & sleeping medications per interquartile range increase in average normalized difference vegetation index around homes**, suggesting that substantial health benefits are possible

#### C. Twohig-Bennett and A. Jones (2018) REVIEW

- Reviewed 143 total articles (103 observational, 40 interventional) investigating ~100 health outcomes until January 2017 & published in English; combined population size of > 290 million in 143 different studies analyzed
- Meta-analysis results showed **increased greenspace exposure associated w/decreased salivary cortisol** [effect mean difference (EMD) -0.05 (95% CI -0.07, -0.04)]

#### Mennis, Mason, and Ambrus (2018) ORIGINAL RESEARCH

- 179 African American adolescents (13-14 years old) recruited between 2012-2014; Participants from Social-Spatial Adolescent Study, a longitudinal study focusing on the contextual mechanisms of adolescent substance use; ecological momentary assessment (EMA) data collection technique that involves repeated sampling of subject's behaviors, moods & experiences in real time & in a subject's natural environment often delivered via brief surveys over mobile phone; survey administered 3-6 times/day over 4-day period every other month over 2 year period during which subject enrolled in study; self-reported stress on continuous 1-9 scale; Age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage; Richmond, VA, USA; used NDVI data derived from Enhanced Thematic Mapper Plus (ETM+) image dated September 12, 2013 carried aboard National Aeronautics and Space Administration (NASA)'s Landsat 8 satellite & downloaded from public sources; 100 m buffer
- Adjusted for age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage
- Markevych et al., 2014 & Bratman et al., 2015 found subjects who took **brief walk in vegetated natural area reduced both mental rumination & neural activity in area of brain associated w/mental illness**, as compared to subjects who took walk in busy, built-up urban area & walks through vegetated park-like settings, as compared to walks through urban areas, have been shown to improve memory span & mood among individuals diagnosed w/depression

- Results indicate that urban greenspace is associated w/lower stress when subjects are away from home possibly due to properties of stress reduction & attention restoration associated w/exposure to natural areas & primacy of other family dynamics mechanisms of stress w/in home
- Greenspace-stress association away from home did not differ by sex, emotional dysregulation, neighborhood disadvantage, or season (season suggesting that observed greenspace-stress relationship associated w/being in natural environment rather than strictly exposure to abundant green vegetation)
- Taylor & Kuo (2009) suggest that greenspace exposure may have particular health effects for youth w/certain mental health conditions & experimental research suggests that **urban youth w/attention deficit/hyperactivity disorder (ADHD) maintain better concentration after exposure to park settings**
- Kuo & Taylor (2004) found that **outdoor activities in natural areas can mitigate symptoms of ADHD among youth**; only setting is significant as moderator (OR = 1.98, p < 0.05) where greenspace associated w/lower stress at EMA responses that occur when subject is away from home
- Speculate that association of greenspace w/lower stress found here due to properties of stress reduction, attention restoration & amelioration of mental fatigue associated w/exposure to vegetation & natural areas among urban residents

Kondo, Fluehr, McKeon, and ... (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- While sample sizes have been small & non-random, and studies are subject to biases associated w/within- & between-subject designs, positive association has been found w/nature exposure
- Astell-Burt et al., (2014) used general health questionnaire to indicate mental health in British Household Panel Survey w/nine annual waves & while adjusting for wide range of individual-level demographics & health behaviors, they found that association between availability of green space & mental health increased in significance & magnitude for both men & women (depending on level of green space) as they aged
- Brown et al., (2014) used questionnaire to assess participants' general, mental & physical health & found that self-reported mental health improved for nature walk group compared to control group that took 2 walks in built urban setting
- Aspinall et al., (2015) was only study to use mobile electroencephalography (EEG) to monitor emotional experience during experimental exposure process & found that participants had more positive emotions & less negative emotions when navigating through urban green spaces compared to built urban spaces
- Beil & Hanes (2013) using w/in-subjects study design found significant improvements in post-exposure measurements of self-reported stress for participants (especially women) exposed to natural urban settings compared to built settings
- General finding among 5 studies (Dadvand et al., (2015), Kuo (2001), Mayer & Frantz (2009), Gidlow et al., (2016), Tyrväinen et al., (2014)] that **exposure to urban nature compared to urban built environments improved multiple measures of cognitive function or development, including attention or attentional capacity & working memory**
- Bratman et al., (2015) found in urban residents, negative associations between rumination & subgenual prefrontal cortex activation & exposure environment (90-min walk in urban nature preserve versus built urban walk) & by time (pre- post-comparisons)
- Gidlow et al., (2016) asked participants to take 30-min walks in natural (green), natural w/water (blue) & residential control (urban) environments & took measurements of psychological &

physiological stress at baseline, at end of walk & **30-min** after **walk** finding **improved attention & restoration only in green & blue environments**

- Dadvand et al., (2015) measured association between green space exposure & aspects of cognitive development including working memory & inattentiveness based on repeated measurements over 1-year period among cohort of children (ages 7–10) in Barcelona finding that adding traffic-related air pollution concentrations to statistical models helped explain 20–65% of estimated positive association between green space (using composite index) & attention
- Tyrväinen et al. (2014) examined psychological (restoration & mood) effects of visits to urban environments (urban park, urban woodland or built urban) finding that **restoration & mood improved in both nature settings, but restoration was more improved in urban woodland**
- Carrus et al., (2015) found association between biodiversity of green space & well-being, mediated by length of park visit & perceived restorativeness
- Butryn and Furst (2003), Song et al., (2014) & Song et al., (2015) used Profile of Mood States (POMS) questionnaire & found **negative association between urban green space exposure & depression**
- Younan et al., (2016) examined association between violent behavior (aggression) & urban green space exposure (average NDVI surrounding residence) using longitudinal cohort study w/four waves finding that increased exposure to green space associated w/reduced aggressive behaviors

Kruize, Vliet, Staatsen, Bell, and ... (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Many studies report positive association between nature experience & stress reduction & improved subjective well-being including happiness; sense of meaning & purpose in life; improved manageability of life tasks; decrease in mental distress & improvements in cognitive function; memory and attention; impulse inhibition; children's school performance & imagination & creativity
- Green space can reduce stress & increase subjective well-being in two ways: 1) **natural areas & features can reduce exposure to challenging environmental conditions by increasing distance to stressors** &/or decreasing their perceptual salience (e.g., green spaces between dwellings & heavily trafficked roads can reduce noise annoyance for residents, vegetation can conceal displeasing structures & landscaping around housing can maintain privacy & avoid sense of crowding & 2) **nature can help people restore their adaptive resources to cope w/stress** & extent to which people are restored by urban green spaces depends on individual perceptions & needs as well as physical characteristics of setting & green spaces can create sense of belonging & decrease social isolation, which may have stress-buffering effect & escape from physical & social stressors has long been described as important motive for recreation in natural areas but appreciation of nature—for its beauty, symbolic qualities & other valued attributes—is another important motive
- World Health Organization [WHO (2016)] report that for individuals who regularly use parks, closer proximity of their home to nearest park was associated w/reduced odds of self-reported symptoms of depression
- Type of interaction w/nature & form of sensory input (e.g., visual, olfactory, auditory, or tactile) may have different impacts on mental health
- Stigsdotter et al., (2010) conducted a study among 21,832 Danish adults & showed that **respondents living more than 1 km away from green space had 1.42 higher odds of experiencing stress than respondents living less than 300 m from green space & those living more than 1 km from green space reported poorer health & health-related quality of life than respondents living closer to green space**

- Barton and Pretty (2010) found in 10 United Kingdom studies multiple mental health benefits from physical activity in green environments
- Van den Berg & Van den Berg (2011) found that **contact w/nature may improve attentional function in children w/attention deficit disorder & enhance self-discipline in children w/out diagnosis**
- Flouri et al., (2014) using data from 6,384 children participating in Millennium Cohort Study, revealed that access to garden & use of parks & playgrounds related to fewer conduct problems (problems related w/antisocial behavior) & fewer peer & hyperactivity problems & poor children aged 3–5 years old & living in urban neighborhoods w/more greenery had fewer emotional problems than their counterparts in less green neighborhoods

Mygind, Kjeldsted, Hartmeyer, Mygind, and ... (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included 1 or more controlled studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight w/in-subjects designs)
- Participants predominantly 11-18 years (≈80%) & ~10% of identified studies included participants <11 (3–7 years ≈3%, 7–11 years ≈ 7%) & children & adolescents w/behavioral and/or emotional disturbances [e.g. attention deficit hyperactivity disorder (ADHD) or depression], substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Mutz & Müller (2016) reported improvements in perceived stress amongst primary school pupils pre to post 9-day hike & university students after 8-day wilderness expedition
- Eight of 11 unique studies from six publications found that nature-based programs improved participants' self-esteem more than comparison conditions (American Institutes for Research, 2005; Hayhurst et al., 2015; Hunter et al., 2013; Kafka et al., 2012; Mann, 2007; Romi and Kohan, 2004) but due to serious risk of bias across studies, quality of evidence considered low
- 5 of 7 unique studies in four publications concluded that **immersive nature-experiences lead to increases in self-efficacy** (Connelly, 2012; Fuller et al., 2017; Hayhurst et al., 2015; Hunter et al., 2010)
- White et al., (2012) found that a 3-month outdoor education program increased self-concept & Larson et al., 2007 found 5-day adventure camp only increased youngest children's (7-11 years of age) self-concept but due to serious risk of bias & indirectness stemming from lack of no treatment control group for three of the studies reviewed (Gehris, 2007; Jelalian et al., 2011, 2006), quality of evidence considered low
- Hohashi & Kobayashi (2013) found fatigue, tension & excitement improved amongst adolescent girls in natural versus urban environments but due to high risk of bias across studies & imprecision introduced by small sample sizes, quality of evidence rated low
- Norton & Watt (2014) found under-resourced urban adolescents 13-18 years old reported improvements in levels & prevalence of depression over course of 7-8 day expedition
- Norton et al., (2007) found adolescents w/diagnosed depression reported lower levels of family conflict post 21-day wilderness therapy program
- When focusing on studies in which control group had been included, outcomes such as self-esteem, self-efficacy, resilience, academic performance, cognitive performance & social skills & behaviors predominantly enhanced by immersive nature-experiences

#### CR Hall and MJ Knuth (2019b) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Younan et al., (2016) found when assessing level of aggressive behavior in young adolescence, both **short-term (1 to 6 month) & long-term (1- to 3-year) exposures to greenspace w/in 1000 m (3,280 feet), surrounding residences associated w/reduced aggressive behaviors** so benefit of increasing vegetation above levels commonly seen in urban environments was equivalent to 2 to 2.5 years of behavioral maturation
- Design of park, its location & people's image of park in combination w/cultural characteristics of various ethnic groups inform opportunities for intercultural interactions leading to social cohesion (Peters et al. 2010); **access to nature is significant predictor of several happiness indicators, even after controlling for other connections** (Zelenski and Nisbet 2014) & results support notion that nature relatedness could be path to human happiness & environmental sustainability (Despard 2016, Glover et al. 2005)

#### C Hall and M Knuth (2019) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- **Time spent in natural settings can help reduce mental fatigue recovery time & improve concentration levels** (Entrix 2010, Keniger et al. 2013, Kjellgren and Buhrkall 2010, White et al. 2017, Wolf and Housley 2014)
- **Increased access to green spaces reduces psychological distress, depression symptoms, clinical anxiety & mood disorders in adults** (Astell-Burt et al. 2013, Beyer et al. 2014, Brown et al. 2013, de Vries et al. 2013, Fan et al. 2011, Nutsford et al. 2013, Stigsdotter 2015, Triguero-Mas et al. 2015, White et al. 2013)
- Women seem to experience more stress than men do when away from nature & Roe et al., (2013b) found that women displayed higher stress levels than men when exposed to same amount of (or less) green space & percent of green space effects showed positive outcome on women by decreasing mean cortisol concentration
- Beil and Hanes (2013) found **greater benefit from exposure to natural settings as measured by pre-and-post changes in salivary alpha-amylase & self-reported stress w/more significant reduction in females than in males**
- Lee et al. (2014) found significant differences between responses of Japanese subjects in forest settings compared w/those in urban environments in salivary cortisol concentration (index of stress response), diastolic blood pressure & pulse rate & subjects felt more comfortable, soothed & refreshed when viewing forest landscape compared to urban landscape
- Mennis (2018) found urban green spaces associated w/lower stress when subjects away from home, possibly due to properties of stress reduction & attention restoration associated w/exposure to natural areas & to influence of other family dynamics affecting stress levels w/in home & that subjects may seek out urban greenspaces at times of lower stress or explicitly for purposes of stress reduction
- Song (2015) found **physiological effects of forest environment can differ depending on subject's initial levels of stress** & that subjects w/high initial blood pressure & pulse rate showed decrease in these values after walking in forested area, whereas those w/low initial values showed an increase
- Comparing household medical records & natural amenities, **residents w/only 10% green space w/in 0.25 mile had 25% greater risk of depression & 30% greater risk of anxiety disorders versus those w/highest degree of green space near home** (Wolf and Housley 2014)
- Aspinall et al. (2015) used EEG headset to measure brain waves by amplitude & frequency, having participants walk through urban shopping center to a 62-acre green space & busy commercial district

with heavy traffic (walk = 25 minutes each) & comparing urban shopping center to green space **found that frustration, engagement & arousal all decreased & when participants moved from greenspace to busy commercial district, arousal/engagement increased**, indicating that stress/fear also increased

- Im et al. (2016) looked at effects of **spending two hours in forest** in Japan & to test neurological effects, they collected blood & saliva samples finding that there was **significant change in level of cytokines contributing to hyperactivity of inflammatory response** which is physiological reaction of stress response
- Joung et al. (2015) showed through near-infrared spectroscopy that total Hb (hemoglobin) concentration significantly lower for forest scenery over urban scenery & lower concentration of total Hb & oxy-Hb indicate that quantity of oxygen transmitted to prefrontal cortex tissue is small i.e., **prefrontal cortex activity in forest area is more stabilized than in urban area**
- Patients who have major depressive disorder (MDD) who walked in nature exhibited **significant increases in memory span after nature walk** relative to urban walk & green spaces **reduced stress & pain & increased attention performance** (McCaffrey et al. 2010)
- In Korean study of patients w/moderate to severe depression, participants assigned to cognitive-behavioral therapy in either hospital setting or arboretum & third group acted as control & treated using standard outpatient care in the community (Wolf and Housley 2014) & overall depressive symptoms reduced most significantly in forest group w/odds of complete remission 20-30% higher than observed from medication alone & **arboretum therapy group had lower levels of stress hormone cortisol & improvements in heart rate variability**
- Berman et al., (2012) found that in Michigan people were **better able to perform test of working memory** (which measures one's ability to focus or concentrate) **after walking through arboretum** compared to those who walked on traffic-heavy urban streets & **subjects who walked through arboretum had 20% improvement in working memory**
- Park et al. (2017) found that when subjects observed plants, Oxy-Hb (oxyhemoglobin) concentrations in right prefrontal cortex significantly lower indicating physiological state of relaxation & subjects reported more positive emotions (feeling more comfortable & relaxed) when viewing foliage plants
- **Children w/ADHD concentrated better after walk in park** than after downtown neighborhood walk (Taylor and Kuo 2009)
- Wilson (2015) showed that **children who play in greenspace for 30 minutes had increased sustained mental ability & found greenspace restorative**
- **Nature exposure can influence cognitive development in children through improved working memory & reduction in inattentiveness** (Dadvand et al. 2015)

Lai, Flies, Weinstein, and Woodward (2019) REVIEW

- Reviewed 275 articles
- Most commonly reported clinical outcomes in reviewed articles were mental, neurological, and behavioral (20%)

Barnes et al. (2019) REVIEW

- Reviewed 30 articles w/41 unique nature-exposure experience locations worldwide
- Participant's experience/ "description/detail of the nature" (or "nature of the nature" as they describe it)
- **Green spaces that elicited mental health benefits could be found across a gradient in terms of sizes ranging from a small 1 ha city park to a 159,000 ha wilderness area**



Roberts, van Lissa, Hagedoorn, Kellar, and Helbich (2019) REVIEW

- Reviewed 33 articles from 10 different countries that investigated the effect of direct, short-term exposure to the natural environment on depressive mood; half of articles were on college students; confounders that were identified include: weather, food, alcohol and caffeine consumption, social interaction with other participants or researchers, environment participants were exposed to immediately before measurements started, and the length of time between the experimental and control environment exposures (if applicable); most studies used forests as their natural environment (n = 16), followed by urban or country parks (n = 11); most studies (n = 24) took mood measurements pre- and post-exposure to nature; all studies examine the effect of short term exposure to green space
- Eleven studies reported a significant decrease in depression pre and post-exposure to the natural environment
- Six studies did not find a significant change in mood; Mao et al. (2012a) and (2017) had participants walk 90 minutes twice a day for seven and four days respectively, both reporting a significant decrease in depressive mood in the forest environment compared to the pre-exposure score; Shin et al. (2011) had participants walk in a forest for 50–55 minutes, and in a city the following week; all POMS subscales, including depression, were found to significantly improve following the forest exposure

Saitta, Devan, Boland, and Perry (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016
- Being physically active perceived to be invigorating experience but **beauty, peace & stillness of being in park brought sense of restoration** & different perspective (Finlay et al., 2015), noted by decreased stress indicators (i.e. salivary cortisol) (Grazuleviciene et al., 2016) **& improvements in self-reported quality of life, spirituality, mood & anxiety** (Nakau et al., 2013)

Wolf et al. (2020) REVIEW

- Reviewed 201 total articles sorted into 3-part framework (Reducing Harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; restoring Capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; Building Capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants
- Of 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults & 13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults; Controlling for socio-economic factors common among cross-sectional studies
- Studies of **clinical populations w/diagnosed mental health conditions found mainly positive results, patients w/major depression disorder** (Kim et al., 2009; Berman et al., 2012) **& exhaustion disorder** (Sonntag-Öström et al., 2014) **who participated in forest-based therapy showed improved outcomes including lower symptoms of depression, remission rates, mood & higher perceived restorativeness**

Grilli and Sacchelli (2020) REVIEW

- Reviewed 36 articles; All reviewed studies report positive impact of exposure to forest environments on measures related to stress & rest regardless of the indicator used

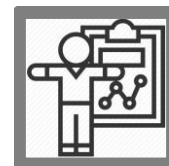
- Three Japanese studies, where forest therapy is often referred to as “shinrin-yoku” (taking in atmosphere of forest), indicate that **spending time in forests helps in reducing cortisol levels & blood pressure & contributing to more stable heartbeat**

Mmako, Courtney-Pratt, and Marsh (2020) REVIEW

- Reviewed 19 articles from high income countries
- Overall finding: Green spaces were shown to have the enabling environment that supports personhood, active citizenship and positive risk taking for people living with dementia; More specifically - green spaces provided a variety of activities for people with dementia, which acted as channels for meaningful engagement; Activities were considered meaningful when they were providing opportunities to be physically active, to find significance and purpose in the activity, and when prompting a desire to make a positive contribution or impact in people's own lives or the wider community; **Active engagement in green spaces was found to boost feelings of self-worth and social connections for people living with dementia**
- Several studies (Noone and Jenkins, 2018; De Bruin et al., 2009; Hall et al., 2018; Cook, 2019; Olsson et al., 2013) reported an increased sense of empowerment among the participants following freedom to independently choose for themselves from the range of activities provided in the green spaces

**Physical Health Benefits of Urban Greenspace**





## Measured / Reported & Perceived Physical Health Benefits of Urban Greenspace

**Summary:** Urban greenspace has been associated with many physical health benefits, and findings from forty-two peer-reviewed articles are documented below. Urban greenspace supports physical activity behavior via accessibility, and has been associated with lower blood pressure (Lachowicz and Jones 2013; Shanahan et al., 2015; Kabisch et al., 2017; Twohig-Bennett and Jones 2018; Hall and Knuth 2019; Wolf et al., 2020), lower heart rate (Twohig-Bennett and Jones 2018; Hall and Knuth 2019; Wolf et al., 2020), lower body mass index (BMI) (Lovell et al., 2014; Tsai et al., 2016; Douglas et al., 2017; Kondo et al., 2018; Fong et al., 2018), and immunoregulatory benefits (Nieuwenhuijsen et al., 2017; Twohig-Bennett and Jones 2018) such as lower resting C-reactive protein levels (Rook 2013), decreased inflammatory cytokines (Hall and Knuth 2019), and improved natural killer cell activity (Hall and Knuth 2019). Though the relationship between urban greenspace and physical activity is confounded by age, sex, socio-economic status (SES), race, income, and perceived neighborhood safety (Chawla 2015; Kondo et al., 2018), it has been consistently suggested that access to greenspace is important for promotion of physical activity for all ages and genders (McCormack et al., 2010; Rakhshanderhoo et al., 2015; D'Alessandro et al., 2015; Kabisch et al., 2015; MacBride-Stewart et al., 2016). Urban greenspace has also been found to contribute to positive birth outcomes (Kabisch et al., 2017; Nesbitt et al., 2017; Abelt and McLafferty 2017; Douglas et al., 2017, Fong et al., 2018) with stronger associations observed among those whose parents had lower levels of education and lower SES (Hall and Knuth 2019). Note: The type of article is indicated to the right of the reference (i.e., “ORIGINAL RESEARCH” or “REVIEW”).

### McCormack, Rock, Toohey, and Hignell (2010) REVIEW

- Reviewed 21 articles; Focus group interviews most common method of collecting data (68%), then individual interviews (67%), then situ observation (24%), w/six studies including multiple data collection methods (29%); several studies include ethnic groups: African Americans, Native Americans, and Latino and Hispanics; socioeconomic status levels of participants varied across studies; seven studies included data collection from children or adolescents
- Traffic & personal safety are important correlates of physical activity
- Urban parks support physical activity through their accessibility
- Evidence that distance from parks inversely associated w/use & physical activity behavior, so creating more neighborhood parks w/in walking distance to most residents could encourage physical activity participation

### Coon et al. (2011) REVIEW

- Reviewed 11 articles w/833 adults & 13 different outcome measures used to evaluate effects of exercise on mental well-being & four outcome measures used to assess attitude to exercise; all included studies measured effects of participating in physical activity on measures of mental well-being shortly following activity (most common mental well-being outcome some measure of an individual's mood or feelings); most studies conducted on University campuses in United States
- Evidence that physical activity in outdoor natural environment may bring additional positive effects on measures of mental well-being not seen when participating in similar physical activity indoors

### Lee and Maheswaran (2011) REVIEW

- Reviewed 35 articles
- Takano et al., (2002) found that availability of green space reported to be independently associated w/increased survival in elderly populations

- Residential proximity to green spaces also associated w/increased levels of physical activity
- **Teenagers living in disadvantaged neighborhoods lacked access to parks they considered safe & were therefore less likely to participate in physical activities than teens in more affluent neighborhoods**

Zhou and Rana (2012) REVIEW

- All kinds of interaction w/green spaces can effectively reduce risk of coronary heart disease & stroke to women & vulnerability of bone fracture can be diminished

Bratman et al. (2012) REVIEW

- Reviewed papers using snowball sample starting with Stephen and Rachel Kaplan and Roger Ulrich - then compiled literature that builds off of these author's work, then a literature search using articles referenced in Kaplan and Ulrich's work, then vague reference to "using computer search engines"; final "n" is not mentioned
- Measured salivary cortisol concentration, diastolic blood pressure & pulse rate while subjects were physically present within each – also fMRI (authors mention this as a future direction as well)

Rook (2013) REVIEW

- Looking at green spaces or walking in parkland or forests cause rapid psychological & physiological changes that can be demonstrated by psychological testing & mobile electroencephalograms & by measurements of cerebral blood flow, various cardiac parameters, blood pressure & salivary cortisol
- Chronic inflammatory disorders that have risen strikingly in prevalence in developed high-income countries usually found to be more common in urban environments from which the immunoregulatory Old Friends are essentially absent & urban increase true for allergies, inflammatory bowel disease & for autoimmune diseases such as multiple sclerosis (MS)
- **Exposure to green spaces will lead to increased immunoregulation, resulting in lower background inflammation**, manifested as lower resting C-reactive protein (CRP) & improved control of inflammation results in lower prevalence of inflammatory disorders, cardiovascular disease & depression & increased stress resilience

Lachowycz and Jones (2013) REVIEW

- Visiting greenspace to interact w/nature or to read book could have benefits to physical health, such as blood pressure reduction (Hartig, Evans, Jamner, Davis, & Garling, 2003) & vitamin D absorption from sunlight exposure (Holick, 2004)

Lovell, Wheeler, Higgins, and ... (2014) REVIEW

- Reviewed 17 published between January 1980 & December 2012 from any country
- Tilt et al. (2007) found interactive effect w/greater objective accessibility related to lower body mass index (BMI) only in areas of higher "greenness" assessed using NDVI
- Poudyal et al., (2009) analysis of secondary aggregate data sets suggested moderate but significant positive association between life expectancy & indicator of exposure to biodiversity in the United States

Moran, Cauwenberg, and ... (2014) REVIEW

- Reviewed 31 articles

- Identified recurring **physical environmental themes** and factors possibly **related to older adults' physical activity (PA) behaviors** & 5 themes emerged from the data: **(1) pedestrian infrastructure, (2) safety, (3) access to facilities, (4) aesthetics, and (5) environmental conditions**

A. M. Dzhambov and D. D. Dimitrova (2014) REVIEW

- Reviewed 24 studies in full & reduced to five studies included in the review
- Two cross-sectional studies analyzed (one high quality and one moderate quality) found that **green areas could buffer effects of chronic noise exposure** on annoyance responses; other study designs (n=2) had mixed results

Haluza et al. (2014) REVIEW

- Reviewed 17 studies most from Japan; not really confounders listed but indicates that the following aspects of studies may have decreased the quality of studies: Factors influencing heterogeneity of outcomes could include low assessment quality, in particular due to participant factors (socio-demographic or disease status), outdoor settings (weather features), type of intervention (components, intensity, timing), and appropriateness of the respective control group and statistical power (small or inadequate sample sizes); 20 different physiological parameters reflecting effects of exposure to outdoor nature were derived from the 17 articles reviewed; most studies were on Japanese male students
- Contact with outdoor nature decreases allostatic load
- Assigned physiological parameters to four body systems: brain activity, cardiovascular system, endocrine system, and immune function
- Positive significant effects found for the cardiovascular system (blood pressure, heart rate variability), endocrine system (e.g., cortisol, blood glucose), immune function (e.g., CD3+ cells) but conflicting results also found in all these areas

Hartig et al. (2014) REVIEW

- Reviewed 59 articles ("review" articles only)
- Outdoor environment may influence how physically active an individual is by offering suitable spaces for certain types of activities & may also attract people outdoors because of the experiences it offers
- Children are most studied subgroup examining nature & physical activity but results of studies have been mixed
- Ding et al., (2011) found that ~40% of the studies in which environmental characteristics were objectively measured showed park access or vegetation to be positively associated with children's physical activity levels

Shanahan, Fuller, Bush, Lin, and ... (2015) REVIEW

- Barton and Pretty (2010) used meta-analytical approach to show greatest effect of green exercise occurs w/in very short (5-minute) time periods
- Improvements in blood pressure can be achieved w/very short periods of exposure to real natural settings & forest bathing experiments in Japan found rapid reductions in heart rate w/in minutes of exposure to natural forest environments
- Barton and Pretty (2010) found 5 minutes of green exercise resulted in greater rate of improvement in feelings of restoration & self-esteem than full day of exposure, suggesting that psychological well-being benefits do not increase linearly w/time

Shanahan, Lin, Bush, and ... (2015) REVIEW

- Hanski et al., (2012) predicted that reduced contact w/natural world & associated microbiota will lead to inadequate stimulation of immunoregulatory circuits & link was discovered by measuring variables at each step of causal pathway, including plant & landscape diversity, microbial diversity in soil & on people's skin, immune function & allergic response

Rakhshandehroo et al. (2015) REVIEW

- Olsson et al., (2012) found that **access to green environment has positive impact on children's physical movement skills & outdoor activities** & increases knowledge & awareness of environmental issues; most children would prefer to play outdoors rather than indoors (Byrne & Sipe, 2010) & they enjoy landscaped spaces of all sizes & dimensions & prefer more secluded landscaped areas (Sarkissian, 2013) as locations w/shady trees & fresh green grass are more conducive environments for children than those devoid of such elements of nature (Singh et al., 2010)

Christian et al. (2015) REVIEW

- Reviewed 32 articles mostly conducted in USA, Australia & Europe w/over two thirds (69%) examining behaviors (e.g., outdoor play & physical activity) through which children develop social-emotional competence, language & communication skills, rather than domains of early child development per se
- In a number of related quasi-experimental studies of 5–7 year olds (n=75), Fjørtoft showed that **children provided w/natural landscape (forest) in which to play, experienced significant increase in motor fitness, balance & coordination** compared w/children who played only in traditional outdoor playgrounds (Fjørtoft, 2004, Fjørtoft and Sageie, 2000, Fjørtoft, 2001)
- Overall outdoor play & physical activity in early years positively associated w/neighborhood greenness (Lovasi et al., 2011, Grigsby-Toussaint et al., 2011), access to nature (Fjørtoft and Sageie, 2000), green public open space (Taylor et al., 1998, Aarts et al., 2010), parks (Roemmich et al., 2006) & playgrounds (Quigg et al., 2011, Sallis et al., 1993)
- Strong empirical evidence that neighborhoods which are safe from traffic & which have green spaces (i.e., nature, public open space, parks, playgrounds) are associated w/behaviors (i.e., outdoor play & physical activity) that facilitate early child health & development

Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using key words "child\*," "youth," "young people," or "adolescents" in combination with "health" or "well-being" and "natural environment," "green space," or "parks"; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); ethnographic work on children in nature in the 1970s and later years was gathered through the author's participation in the development of this field
- Confounders adjusted for in articles included air pollution, noise, temperature where confounders noted in the section on physical health
- Access to green space and increased physical activity; also true for street trees
- **Proximity to parks and other green spaces linked to healthier weight or lower body mass index in children**

- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety
- Protective effects of nature at birth including higher birthweight with higher levels of greenness

#### D'Alessandro et al. (2015) REVIEW

- Results section indicates search but then different article cited; number of citations do not match up with references: "A «web of knowledge» search with just two terms, «green space and health», yielded 2 hits for 1990-1999, 34 for 2000-2009, and 45 from 2010 to June 2013; in the same paper; authors performed a «review of reviews» on the topic until April 2013, involving 56 relevant reviews 2009, and 45 from 2010 to June 2013"
- Contact with nature may affect health via multiple pathways, that have received relatively large amounts of research attention: air quality, social cohesion, stress reduction, and physical activity
- **Major determinant of physical activity is access to green spaces**

#### Kabisch, Qureshi, and Haase (2015) REVIEW

- Reviewed 219 articles published in English between 1 January 2000 & 1 October 2013; 40% of all studies applied questionnaire surveys which included interviews, focus groups, or observations applied followed by analyses using GIS
- Wolch et al. (2011) assessed relationship between childhood obesity & proximity to urban parks in longitudinal study in California finding that **accessibility & available parkland had significant impact on weight**

#### Webster (2015) REVIEW

- Hypothetical causal pathways green space: health green space moderates extreme temperatures, enhances thermal comfort through evaporative cooling reduces glare (ocular health), trees mitigate effect of wind and decrease noise
- Greenery generates oxygen, reduces air pollution
- Preservation of biodiversity
- Trees reduce accidents

#### Eisenman (2016) REVIEW

- Many studies now show beneficial links between green space and physician assessed morbidity, risk of stroke and mortality, human immune function, birth outcomes (e.g., gestational weight)
- Mixed results have been found in studies on green space and obesity

#### MacBride-Stewart et al. (2016) REVIEW

- Problems within local neighborhood, such as lack of amenities or poor quality air and reputation of the local area were more likely to negatively influence women's physical health and their activities in that space more than men, often due to concerns over personal safety
- Not just access to green space but rather **access to large green space important for physical activity (all genders)**

#### Tsai, Floyd, Leung, McHale, and ... (2016) ORIGINAL RESEARCH



- Examined 135 United States counties w/both health data & land cover data available & used Behavioral Risk Factor Surveillance System 2008 for physical activity (self-reported) & BMI (calculated) data; used National Land Cover Database 2006
- Adjusted for total population, total housing units, median household income & percent black/African American population for each county obtained from American FactFinder, US Census Bureau & treated as confounding
- More connections between forest & developed area ( $\beta=0.37$ ,  $p<0.01$ ) & greater edge density of shrub land ( $\beta=0.646$ ,  $p<0.001$ ) positively associated w/higher % of normal BMI (<25) within counties; all three vegetative covers (forest, shrub land & herbaceous) significantly positively correlated w/physical activity; results showed more physical activity associated w/greater amounts of vegetative cover at county scale based on bivariate analyses
- J.H. Tilt et al., (2007) found **lower BMI among adults observed in high greenspace (measured by NDVI) neighborhoods w/more destinations for walking than in less green neighborhoods**

#### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles & restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Two studies investigating effect of green space availability on overweight in preschool-aged children (Kabisch et al., 2016, Schüle et al., 2016) found that individual child & parental factors (parental overweight, low- and middle-level parental education or social status) main predictors of overweight, while urban green space availability not independently associated w/overweight
- Markevych et al., (2014) found association between lower systolic blood pressure levels in 10-year-old children living in urban residences & higher greenness using NDVI
- Proximity to green space (near homes of residents) may improve longevity of senior citizens (Takano et al., 2002)
- Results from studies on relationship between urban green & neonatal outcomes (e.g., birth weight) showed positive trend but were somewhat inconsistent

#### Nieuwenhuijsen et al. (2017) REVIEW

- Newly promoted biodiversity hypothesis suggests that **reduced contact w/nature may adversely affect human commensal microbiota & its immunomodulatory capacity**
- Hanski et al., (2012) found relationship between generic composition of skin microbiota & land use type around home; also found reduced level of allergic disease, mediated through acinetobacter & gammaproteobacteria, but few studies so far have focused on this mechanism
- Moore (2015) recently suggested "biogenics" hypothesis, suggesting that **regular exposure to low concentrations of mixtures of natural compounds & toxins in natural environments confers pleiotropic health benefits by inhibiting activities of interconnected cell signaling systems, particularly PI3K/Akt/mTORC1 & when overactive, Akt & mTOR (mTORC1) can lead to pathological processes resulting in cancers, diabetes, inflammation, immunosuppression & neurodegenerative diseases**

#### E. Ekkel and Vries (2017) REVIEW

- Gražulevičienė et al., (2014) found having **access to green, recreational space w/in 300 m associated w/lower probability of high-normal blood pressure during pregnancy**

#### Bosch and Sang (2017) REVIEW

- Reviewed 13 total peer-reviewed articles written in English found in April 2016 ("only 3 of those were retrieved if including health in the search terms")
- Gascon et al., (2016) found moderate to strong evidence for association between natural environments & CVD-mortality

#### L. Nesbitt, Hotte, Barron, Cowan, and Sheppard (2017) REVIEW

- Reviewed 38 articles focused on North America that examined the services of mixed vegetation (i.e., multiple or unspecified types of vegetation), 31 studies that examined the services of trees & 43 studies that examined the services of green spaces
- Neighborhood greenness appears to be linked to positive birth outcomes in a variety of contexts (Dadvand et al., 2012a, Dadvand et al., 2012b, Donovan et al., 2011, Hystad et al., 2014)
- Donovan et al. (2011) found that 10% increase in tree canopy cover within 50 m of house was correlated with fewer small for gestational age births in Portland, Oregon, while controlling for household income
- Urban greenery can reduce childhood obesity

#### Abelt and McLafferty (2017) ORIGINAL RESEARCH

- Analyzed birth records for year 2000 provided by New York City Department of Health & Mental Hygiene for total of 103,484 singleton births to mothers who resided w/in New York City, NY limits; used Normalized Difference Vegetation Index (NDVI) & NYC Street Tree Census as measure of greenness; adjusted for individual factors - maternal & infant characteristics demonstrated to affect birth outcomes; infant's sex and season of birth; adjusted for neighborhood factors - socioeconomic status, tract-level deprivation index created based on eight variables: 1) percent of female-headed households w/children under 18 & no husband present, 2) percent of households receiving public assistance income, 3) percent of households whose yearly income <\$35,000, 4) percent of individuals living below poverty line, 5) percent of individuals over 16 years old unemployed, 6) percent of employed individuals over 16 years old who worked in management or professional occupations, 7) percent of adults over 25 years old w/less than 12th grade education & 8) percent of occupied housing units w/1+ occupant per room
- Significant association between street trees surrounding home & reduced odds of preterm birth; access to major green spaces not significantly related to odds of preterm birth in these models nor were any of other neighborhood-level covariates
- Access to major green spaces & neighborhood covariates not significantly associated w/small for gestational age in models
- Most notable finding evidence of inverse relationship between local street trees & increased odds of preterm birth
- Recent investigations into association between green space & birth outcomes have demonstrated relatively consistent results (n=13 studies) which examined variety of outcomes, but all included at least one outcome related to birthweight &/or gestational age & in all but two cases & NDVI used as primary measure of greenness
- Results of these studies provide support for protective relationship between green space & birthweight as significant positive association between greenness & birthweight-related variables observed for at least subset of population in all studies
- Studies found stronger associations between greenness & decreased risk of adverse birth outcomes among women of lower socioeconomic status (n=5)

#### O. Douglas, M. Lennon, and M. Scott (2017) REVIEW

- **Perceived lack of green space & low playground space have been independently associated w/being overweight in pre-school children**; see note w/Sugiyama et al. (2008); relevant for urban planners providing green space access to urban population & life course approach important to present day
- More convincingly, robust prospective survival analysis by Villeneuve et al. (2012) linked higher levels of greenness w/lower risk of CVD & reduced risk of ischemic heart disease & stroke mortality after adjustment for ambient air pollution
- Astell-Burt et al., (2014) found risk of type-2 diabetes significantly lower in greener neighborhoods, controlling for demographic & cultural factors, especially among participants residing in neighborhoods w/41–60% green space land use & association consistent after controlling for other explanatory variables & did not vary according to neighborhood circumstances
- Important to focus on adolescent group since prone to physical inactivity & studies show that people more likely to be physically active as adults if they were physically active in late teens
- Important from health standpoint since childhood inactivity has been identified as key risk factor in many chronic diseases of later life & early socially-stimulating environments have been shown to strongly inform later emotional well-being & cognitive capacity
- Almanza et al., (2012) found higher odds of physical activity identified among 8–14 year olds when in greener areas compared to less green areas
- Prospective study including children & youth aged 3–16 years by Bell, Wilson, and Liu (2008) found that higher greenness significantly associated w/lower Body Mass Index (BMI) values after 24 months
- 32 studies explored environmental characteristics contributing to physical activity among youth (age 8–21); the characteristic most frequently reported to promote physical activity was access to green space, measured either as distance from one's home to parks & green areas, or as percent green coverage or number of recreational facilities in neighborhood; the higher amount & closer distance was equal to more park use w/positive effect on physical activity
- Villeneuve et al., (2012) found increased exposure to greenness proximate to place of residence linked w/reduced overall non-accidental mortality among elderly inhabitants
- Effect of greenness on pregnancy & birth outcomes studied extensively & positive associations between greenness & birth weight of babies observed across majority of studies
- Studies found linked increased exposure of pregnant mothers to green space w/lower odds of child being small for gestational age or preterm/premature & lower infant mortality risk
- Research showed that exposure by pregnant women to green space & nature may have affected birth outcomes by altering their levels of physical activity, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise & air pollution exposure & moderating ambient temperatures
- Majority of analyses have adjusted for race, maternal age, season of conception, area-level socio-economic factors & child's sex w/consistent results identified

#### C Twohig-Bennett and A Jones (2018) REVIEW

- Reviewed 143 total articles (n = 103 observational, n = 40 interventional) investigating ~100 health outcomes until January 2017 & published in English; combined population size of > 290 million in 143 different studies analyzed
- **Physical activity in natural outdoor environment associated w/reduced negative emotions & fatigue, increased energy** (Bowler et al., 2010, Thompson Coon JB et al., 2011), **improved attention & greater satisfaction, enjoyment & greater intent to repeat activity** (Bowler et al., 2010); Meta-analysis results showed **increased greenspace exposure associated w/heart rate**

[effect mean difference (EMD) -2.57 (95% CI -4.30, -0.83)], **diastolic blood pressure** [EMD -1.97 (95% CI -3.45, -0.19)], **HDL cholesterol** [EMD -0.03 (95% CI -0.05, <-0.01)], **low frequency heart rate variability** (HRV) [EMD -0.06 (95% CI -0.08, -0.03)] & **increased high frequency HRV** [EMD 91.87 (95% CI 50.92, 132.82)], **type II diabetes** [odds ratio (OR) 0.72 (95% CI 0.61, 0.85)], **all-cause mortality** [OR 0.69 (95% CI 0.55, 0.87)], **cardiovascular mortality** [OR 0.84 (95% CI 0.76, 0.93)]

- Meta-analysis results showed **increased greenspace exposure associated w/decreased risk of preterm birth** 0.87 (95% CI 0.80, 0.94), **small size for gestational age** 0.81 (95% CI 0.76, 0.86)
- Two studies reporting on cancer outcomes & found that living in highest quartile of greenspace associated w/significantly reduced risk of prostate cancer (Demoury et al., 2017), OR 0.82 (95% CI 0.72, 0.92) & reduced incidence of overall cancer mortality HR 0.87 (95% CI 0.78, 0.97) (James et al., 2016)
- Meta-analysis results showed increased greenspace exposure associated w/increased incidence of good self-reported health 1.12 (95% CI 1.05, 1.19); **Exposure to diverse variety of bacteria present in natural areas may convey immunoregulatory benefits & reduce inflammation** (Rook, 2013)
- Much of literature on forest bathing suggests that phytoncides (volatile organic compounds w/antibacterial properties) released by trees may explain salutogenic properties of shinrin yoku (Li et al., 2009, Tsunetsugu et al., 2010)

#### Kondo et al. (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- Majority of evidence suggests no association between BMI & urban green space exposure but no studies reviewed explored physical activity, cardiovascular disease or mental health, which are expected to be pathways of association, as effect modifiers
- Exposure to green space may affect cardiovascular system by way of mitigating harm (e.g., air & noise pollution & heat), restoring mental capacities (e.g., attention restoration or stress recovery), or building capacities (e.g., physical activity, social connectedness)
- Grazuleviciene et al., (2016) based on a small sample found that **group that walked in urban park had greater reductions in diastolic blood pressure (DBP) & HR & increases in HR recovery** when comparing pre- & post-measurements
- While studies in general found negative association between urban nature exposure & heart rate, these studies were predominantly based on small sample size & did not control for confounding factors
- Few consistent measures of heart rate variability have been used in small number of studies & findings are mixed
- Tamosiunas et al., (2014) measured association between green space exposure (distance from residence to nearest park & self-reported park use) & markers of CVD among cohort of residents (ages 45–72) of Kaunas City, Lithuania finding that after controlling for both individual-level demographic & health behaviors (smoking & physical activity) that there was **increased risk of fatal & non-fatal CVD for participants (especially men) that lived further from green spaces** & increased risk of non-fatal CVD among non-park users that lived further from green spaces
- Odds of MVPA higher for study participants when spending time in parks than in other land uses [Oreskovic et al., (2015), Rodriguez et al., (2012), Sellers et al., (2012)]
- Wolch et al., (2011) examined association between proximity to parks w/childhood obesity using data from eight annual survey waves from longitudinal cohort study of 3,173 children in California & while controlling for multiple potential confounding factors, **BMI growth at age 18 inversely associated w/park access (park acres w/in 500 m of residence) more so for boys than for girls**

- Lachowycz et al., (2012) found that **up to 30% of moderate-to-vigorous physical activity (MVPA) among 10–11-year-olds was done in parks**, tracking location of MVPA using combination of wearable global positioning system (GPS) & accelerometer
- Almanza et al., (2012) found that **MPVA nearly 5 times greater among children that spent more than 20 minutes of time in green space**, than among children w/no green space exposure
- Cusack et al., (2017) measured maternal residential green space in metropolitan areas of Texas for 3,026,603 births at 1st, 2nd & 3rd trimesters & for total pregnancy, controlling for known individual & neighborhood confounding factors (e.g., demographic background & smoking status) & did not find consistent effects on birth weight, odds of preterm birth or small for gestational age but did find some protective effects of increased residential greenness for mothers with low education, mothers that lived in low-income neighborhoods, or for Hispanic mothers
- Demoury et al., (2017) examined whether residential green space exposure related to prostate cancer incidence using population-based case-control study & when controlling for individual factors (demographic background; family & medical history; smoking, alcohol, diet & physical activity-related behaviors) they found that **increased residential greenness associated w/lower risk of cancer**
- Crouse et al., (2017) conducted large cohort study of mortality among non-immigrant Canadians residing in 30 cities between 2001 & 2011 & using annual measurements of residential green space, they found protective association w/non-accidental, cardiovascular (plus diabetes), cardiovascular, ischemic heart disease, cerebrovascular & respiratory mortality & finding that sex, age, income, educational attainment & marriage status modified estimates

#### Fong, Hart, and James (2018) REVIEW

- Reviewed articles published January 2015 to October 2017
- Three studies in which physical activity objectively measured by hip-worn accelerometers, positive associations between greenness & physical activity found, despite fact that studies processed accelerometry data in different ways (Dewulf et al., 2016, Markevych et al., 2016, James et al., 2017)
- Sarkar (2017) found among cross-sectional study w/highly spatially resolved NDVI data at 0.5 m resolution that among 333,183 adult participants across the United Kingdom an interquartile range (IQR) (0.24) increase in NDVI in 500 m area around participant's home associated w/9.3% (95% CI: 8, 11) increase in odds of using active travel (walking, cycling, or public transport) for non-work trips & 3.9% (95% CI: 3, 5) increase in odds of walking for physical activity more than 30 minutes per day; also found BMI was 0.12 (95% CI: 0.10, 0.14) kg/m<sup>2</sup> lower, waist circumference was 0.55 (95% CI: 0.50, 0.61) cm less & whole body fat mass levels (measured through bio-impedance) were 0.14 (95% CI: 0.10, 0.18) kg lower & overall found that IQR increase in NDVI associated w/3.2% (95% CI: 2.0, 4.0) lower odds of obesity & anthropometry was measured using trained technicians, which likely improves accuracy of adiposity measures
- Maternal exposure to greenness thought to affect birth outcomes via increasing physical activity, improving mental health & buffering detrimental effects of air pollution, noise & extreme heat exposures
- Cusack et al., (2017) did large birth cohort study in Texas examining 3 million+ births & found that **among full-term births, birth weight higher when NDVI levels during pregnancies higher & those children born to mothers living in greenest areas (NDVI >0.52) had on average 1.9 grams (95% CI 0.1, 3.7) higher birth weight compared w/those born to mothers who lived in least green areas (NDVI <0.37)** & evidence that SES-related variables such as ethnicity, education & neighborhood characteristics modified relationship between greenness & birth outcomes w/strongest associations observed in lower SES groups

- Higher odds of preterm birth, defined as being born at <37 weeks of gestation associated w/lower exposures to greenness & green spaces around maternal residence in some studies
- Bijmens et al., (2015) employed novel biomarker & assessed telomere length in umbilical cord blood cells collected 24 hours after delivery; short telomere lengths have been used as measure of accelerated aging & short telomere lengths in cord blood cells been linked to early insulin resistance & impaired fetal growth & brain development in children & **found 22% increase in proportion of green space 5000 m around maternal residence associated w/on average 3.62 (95% CI: 0.20, 7.15) % longer telomere**
- James et al., (2016) conducted prospective cohort study analyzing data from 108,630 female nurses in US followed for 627,008 person-years from 2000–2008 & found that per 0.1 NDVI increase, their mortality was 12% (95% CI: 6, 18) lower but strongest findings were for cancer & respiratory mortality & mediation analyses suggested that mental health pathway explained 30% of association
- For most mortality outcomes, associations stronger in urban communities, among younger individuals & in women & highest SES individuals
- Consistent & strong evidence that higher levels of greenness associated w/higher birth weights, higher levels of physical activity & lower mortality rates
- Consistent evidence across large-scale prospective studies in multiple countries suggests that greenness lowers mortality rates overall

#### Mygind et al. (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included 1 or more controlled studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight with in-subjects designs)
- Participants predominantly 11-18 years (≈80%) & ~10% of identified studies included participants <11 (3–7 years ≈3%, 7–11 years ≈ 7%) & children & adolescents w/behavioral and/or emotional disturbances (e.g. attention deficit hyperactivity disorder (ADHD) or depression), substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Number of identified controlled studies exploring benefits to physical health limited (n=5)

#### CR Hall and MJ Knuth (2019a) REVIEW

- 1,348 total citations compiled & 2/3 conducted since 2011
- **Interacting w/plants counters adverse effects of stress on energy metabolism, insulin secretion, inflammatory pathways** (Bhasin et al. 2013) & ultimately diabetes & obesity (Astell-Burt et al. 2014, Bodicoat et al. 2014, Lachowycz and Jones 2011, Thiering et al. 2016)
- Walking in natural areas or improved landscapes (outdoor landscape spaces that have been “improved” aesthetically) results in **healthier levels of hormone dehydroepiandrosterone in bloodstream (DHEA)** (Ohtsuka 1998) & DHEA has **cardio-protective, anti-obesity & anti-diabetic properties** (Bjørnerem et al. 2004) so regular exposure to natural areas helps protect against obesity, type II diabetes, hypertension & coronary heart disease
- In diabetic patients, monthly nature walks sufficient to reduce glycated hemoglobin (HbA1c) to just below threshold value for diabetes diagnosis so not surprising that diabetes mellitus (Type 1 or 2) less prevalent among individuals living in greener surroundings (Astell-Burt et al. 2014, Maas et al. 2009) & among public park users than non-park-users (Tamosiunas et al. 2014)

- Consistent w/“hygiene hypothesis”, **contact w/microbial & other antigens in natural settings during particular developmental windows may improve immune function over lifespan** (Hanski et al. 2012, Kondrashova et al. 2013, Nicolaou et al. 2005, Rook 2013, Ruokolainen et al. 2015, Stiemsma et al. 2015) **perhaps operating through effects on microbiome** (Lee and Mazmanian 2010) & **short-term exposure to natural substances (such as phytoncides from trees) have been associated w/improved natural killer (NK) cell activity** (Li 2010, Li and Kawada 2011, Li et al. 2008a, Li et al. 2008b, Li et al. 2006) & NK cells **play important protective roles against cancer, viral infections & inflammatory cytokines that have been implicated in diabetes, cardiovascular disease, depression** & other negative health outcomes (Cesari et al. 2003, Dowlati et al. 2010, Orange and Ballas 2006, Wellen and Hotamisligil 2005)
- Fantuzzi (2013) found that **adiponectin levels in body increase while in nature** & improved landscapes (Li and Kawada 2011) **which helps protect against atherosclerosis, acute urinary tract infections, infectious diseases of intestinal canal & upper respiratory tract infections**
- Illnesses associated w/failing immunoregulation & poorly-regulated inflammatory responses, manifested as chronically raised levels of C-reactive protein & proinflammatory cytokines, are mitigated through exposure to plant-filled nature, reducing levels of these inflammatory cytokines (Mao et al. 2012) & **extended time in nature decreased inflammatory cytokines implicated in chronic disease by roughly half**
- **Environmental biodiversity has been proposed to contribute to human commensal microbiota** (i.e., “good bacteria” living on or in human body) & more access that children have to natural settings in which to play, more proteobacteria on their skin & more diverse their gamma-proteobacteria (Hanski et al. 2012, Ruokolainen et al. 2015)
- Walks in nature have a number of positive short-term effects on cardiovascular system by raising serum levels of adiponectin – which is anti-atherogenic & DHEA – which is cardio protective & in hypertensive patients, **walks in nature decrease serum levels of number of factors associated w/high blood pressure: endothelin-1, homocysteine, renin, angiotensin II type 1 receptor & angiotensin II type 2 receptor** (Mao et al. 2012) so not surprisingly these walks lower blood pressure in young & middle-aged adults (Li 2010, Park et al. 2010) & older adults w/hypertension (Mao et al. 2012)
- **Average heart rates of low-income African American males when walking past landscaped sites went from 103.3 beats per minute (bpm) before greening to 107.2 bpm after greening for total increase of 3.9 bpm** & when in view of non-landscaped vacant lots, average heart rate went from 99.6 bpm in pre-intervention period to 109.1 bpm in post-intervention period for total increase of 9.5 bpm so final estimate between landscaped & non-landscaped vacant lots was lower w/heart rate of 5.6 bpm (South et al. 2015)
- People who live in close proximity to green spaces are three times more likely to engage in physical activity & 40% less likely to be overweight (Watson and Moore 2011) & having clean parks & **nearby park access associated w/healthier weights & greater life satisfaction** amongst users
- Stark et al., (2014) showed greater availability of neighborhood parks (either large or small) & greater park cleanliness to be associated w/healthier weights among adults after adjusting for neighborhood features that could influence park use, such as walkability & violent crime
- Dadvand et al., (2012a) found **greater exposure to plants affects birth outcomes by altering increasing maternal levels of physical activity, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise & air pollution exposure & moderating ambient temperatures**
- Higher greenness exposure linked to lower odds of child being small for gestational age or preterm (Hystad et al. 2014), larger head circumferences (Dadvand et al. 2012a) & lower infant mortality risk

- Stronger associations between greenness & birth outcomes observed among those whose parents had lower levels of education & lower socio-economic status (Agay-Shay et al. 2014, Dadvand et al. 2012a, Markevych et al. 2014)
- Individuals further from green spaces less likely to partake in physical activity & had higher odds of obesity than those living closer (Toftager et al. 2011, Lachowycz and Jones 2011)
- Dadvand et al., (2014b) found **interquartile increase in residential surrounding greenness associated w/11–19% lower relative prevalence of being overweight or obese** (residential proximity to green spaces was defined as living w/in 300 m of forest or park) & residential proximity to green spaces associated w/39% decrease in excessive screen time & 25% lower incidence of obesity
- **Periods of moderate–to-vigorous physical activity significantly more likely to occur in green spaces for boys**, but relationship was positive but not statistically significant for girls (Wheeler et al. 2010)
- **Children & adolescents w/better access to parks less likely to have higher BMI levels** (Wolch et al. 2011) & level of children's physical activity seems influenced by access to parks & vegetation (Ding et al. 2011)
- Multiple studies have reported **allergies, asthma & eczema (which all reflect hypersensitivity of immune system) less prevalent among persons w/greener residential surroundings** (Fuertes et al. 2014, Hanski et al. 2012, Lovasi et al. 2008, Maas et al. 2009, Ruokolainen et al. 2015)

#### Hunter et al. (2019) REVIEW

- Reviewed 39 studies from high income countries (e.g., US, UK, AUS)
- Five of these seven studies showed significantly positive post-intervention effect for increasing park usage and physical activity following: major improvements to playing fields of public parks

#### Saitta et al. (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016
- Participants purposefully used parks to maintain their physical health, to foster physical play & for individual specific physical rehabilitation & reported feeling 'healthy' just being in park & perceived that they were motivated to exercise in natural environment thereby increasing their mobility, joint movement & manual dexterity
- Physical health gains from physical activity in children & adolescents appear to be incidental & were gained primarily via play in park (Jeanes & Magee 2012; Ripat & Becker 2012)
- Physical activity in park reported as intentional as parks provided place & purpose for rehabilitation as well as perception that they would mitigate deteriorating health in social environment (Chow 2013; Finlay et al., 2015)

#### Lai et al. (2019) REVIEW

- Reviewed 275 articles
- Result is very general but included because of high sample size; most quantitative studies of health effects of green space (n = 173, 87%) reported protective effects
- Several review papers have hypothesized that exposure to microbial biodiversity may benefit immunoregulatory functions (Rook 2013; Rook et al. 2014) & that **transmission of pathogens may occur less rapidly in biologically complex green areas** (Rook et al. 2014)



## Kruize et al. (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Gidlow et al., (2016) compared psychological & physiological responses of 38 unstressed individuals to self-paced 30 min walks in three environments: residential (urban), natural (green) & natural w/water (blue) & mood, cognitive function, restoration experiences, salivary cortisol & heart rate variability (HRV) measured at baseline (T1) to T2 (end of 30 min walk) & T3 (30 min after leaving environment) finding that **stress reduction in all environments pointed to salutogenic effect of walking, but natural environments conferred additional cognitive benefits lasting at least 30-min after leaving environment**
- Another suggested immunological pathway is through **exposure to diverse microorganisms in green space which can play immunoregulatory role** & Hanski et al., (2012) found in 118 adolescents in eastern Finland that, compared w/healthy individuals, atopic individuals had lower environmental biodiversity in surroundings of their homes & significantly lower generic diversity of gammaproteobacteria on their skin, that help to prevent people from having allergic reactions so these results raise fundamental questions about consequences of biodiversity loss for both allergic conditions & population health in general
- Japanese studies have demonstrated associations between visiting forests & beneficial immune responses, including expression of anti-cancer proteins suggesting that immune systems may benefit from relaxation provided by natural environment & through contact w/certain physical or chemical factors in green space & it has been shown that children w/highest exposure to specific allergens & bacteria during their first year were less likely to have recurrent wheezing & allergic sensitization

## Wolf et al. (2020) REVIEW

- Of 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults & 13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults
- 201 total articles sorted into 3-part framework (reducing harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; restoring capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; building capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants; controlling for socio-economic factors common among cross-sectional studies
- Song et al., (2016) found that smelling volatile organic chemicals (VOCs) derived from *Cedrus deodara* can lead to increased relaxation & blood oxygenation w/improvements to respiratory or circulatory system & decreased blood pressure
- Ohtsuka et al., (1998) found significantly lower blood glucose, HbA1c & blood pressure in longitudinal study of non-insulin dependent diabetic patients who participated in forest walks on 9 occasions over 6-year time span; **positive associations at individual level between certain measures of tree exposure & reduced BMI, including: more tree patches & well-connected urban forests & trees** (Kim et al., 2014); greater proximity to forests (Dadvand et al., 2014)
- **Increased NK activity can last 7+ days after forest trip** (Li et al., 2008; Li et al., 2008b; Li et al., 2010); Li et al., (2009) suggest that higher concentrations of phytoncides (aromatic VOCs released by trees) typically found in forest settings may contribute to increased NK activity
- Forest bathing improved cardiovascular function & related health outcomes among healthy participants, including: increased parasympathetic activity & reduced heart rate (Li et al., 2014);

lower blood pressure (Li et al., 2011; Song et al., 2017); lower heart rate, diastolic blood pressure, and sympathetic activity (Park et al., 2009)

- Seo et al., (2015) found that **among children w/asthma or atopic dermatitis, short visit to forest resulted in significant improvements in various measures of disease severity & immunological effects**
- Mao et al., (2012) found that among participants w/cardiovascular disease, **exposure to forest settings found to improve symptoms of hypertension** more than urban settings, including: lower blood pressure & homocysteine (a CVD-related pathological factor) in elderly adults

Hartley, Ryan, Brokamp, and Gillespie (2020) REVIEW

- Reviewed 7 articles; 6/7 studies used NDVI
- Out of the seven reviewed papers, six reported no statistically significant direct relationships between greenness and child asthma while one (Donovan et al., 2018) found one **standard deviation increase in NDVI was associated with a 6% lower risk of asthma** (95% CI: 1.9%-9.9%)
- Three papers reported **greenness was protective for child asthma via mediation of other negatively related health factors, such as difficult family relationships** (Chen et al., 2017), **high traffic volume** (Feng & Astell-Burt, 2017), **and tobacco smoke exposure** (Eldeirawi et al., 2019)
- **Greenness** has no direct effect on child asthma but **may be protective via modification of individual and community-level risk factors**

Mmako et al. (2020) REVIEW

- Reviewed 19 articles from high income countries
- Opportunities for positive risk taking that green spaces can afford and positive risk-taking allowed people living with dementia to live richer lives while also developing coping mechanisms to effectively navigate through daily life
- Risk negotiation is important to allow for improvement of adaptive skills, which are very useful in dementia process

**Social / Other Health Benefits of Urban Greenspace**





## Measured / Reported & Perceived Social / Other Health Benefits of Urban Greenspace

**Summary:** Urban greenspace has been associated with many social health benefits, and our structured literature review revealed relevant findings from forty-five peer-reviewed articles. Ultimately, inclusive urban greenspaces can help residents develop a sense of community (Douglas et al., 2017), increase social cohesion (Nieuwenhuijsen et al., 2017), and reduce feelings of isolation (Nesbitt et al., 2017; Kruize et al., 2019). More social ties among inner city residents were found for those who had greater access to greenspace (Zhou and Rana 2012), highlighting the importance of inclusive and accessible greenspaces. In addition, aspects of urban greenspace can provide children with a range of sensory experiences to help refine motor and social skills (Rakhshandehroo et al., 2015). At the same time, aspects of urban greenspace can help older adults generate feelings of attachment to community (Douglas et al., 2017) and empower the social confidence of persons with disabilities (Saitta et al., 2019). However, in some cases, social perceptions of accessibility were found to be important drivers of health, more so than having physical access to an urban greenspace (Lachowycz and Jones 2013). Other aspects of well-being, such as elevated feelings of awe, inspiration, and spirituality can be invoked from immersion in the various sights and sounds of nature (e.g., fractal patterns found in trees) (Capaldi et al., 2015). Note: The type of article is indicated to the right of the reference (i.e., “ORIGINAL RESEARCH” or “REVIEW”).

### Smardon (1988) REVIEW

- More (1985) found that in study of two large urban parks in Boston, MA & Hartford, CT following findings relate to recreational activities and urban vegetation - **grass correlates positively w/sleeping, indulging & eating & in Boston also correlated w/eating & play & number of trees positively correlated w/many activities but especially w/sleeping & reading & in Boston**, number of trees in sector also correlated w/conversing, eating, play, music/dance, feeding & indulging. while large trees fostered conversing, play, reading & sleeping in both cities but in Boston only, they were positively associated w/feeding, indulging, eating & music/dance
- Often forgotten sensory function stimulated by urban vegetation is smell (Gibbon et al., 1986) & trees & vegetation exude scents & odors that, on the whole are appealing & stimulating
- Appleyard et al., (1980) found that scent of pine trees, especially after rain, conjures up vivid memories of certain experiences or associations
- Can be **positive urban sounds** (Southworth, 1969) among them sounds of **rustling leaves, creaking branches & whistling of wind, sometimes birds nesting in trees supply music** (Appleyard, 1980); study of diverse sample of 250 residents of inner city areas of Detroit (70% black subjects; 30% white) concluded there was broad agreement in terms of strongly positive feelings for trees in cities (Getz et al., 1982)
- Kalmbach & Kielbaso (1978) study of street tree plantings in five Midwestern cities, street trees >25 feet tall aesthetically preferable to smaller trees & street tree planting densities of one tree per house appear satisfactory to a large segment of the population

### Gearin and Kahle (2006) ORIGINAL RESEARCH

- 16 high school seniors (n = 5 girls, n = 11 boys; n = 15 Hispanic, n = 1 Asian-American) & adults in Los Angeles, CA, US; focus group & survey
- Attitudes towards urban open &/or green space revolved around multiple uses for park space, safety issues & concerns about trash & maintenance
- Ten separate responses related to issues of personal safety offered during discussion; some perceived streets as potentially unsafe areas in which to recreate or socialize & particular streets unsafe because of history of violent activities & traffic

- Preference for places that offer range of activities centered on socializing; teens identified places typically overlooked in terms of greening opportunities, such as neighborhood underpass (tunnel) & local alleyways
- Possible that being outside in environment less bound by rules than school library resulted in greater sense of speaking comfort & encouraged more responses
- Urban teenagers participating in research—living in a park-poor, high density area—aware of & had experienced personal & collective benefits from parks

#### McCormack et al. (2010) REVIEW

- Reviewed 21 articles; focus group interviews most common method of collecting data (68%), then individual interviews (67%), then situ observation (24%), w/six studies including multiple data collection methods (29%); several studies include ethnic groups: African Americans, Native Americans, and Latino and Hispanics; socioeconomic status levels of participants varied across studies; seven studies included data collection from children or adolescents
- Studies involving children/adolescents indicated **access to variety of facilities in parks that supported active & passive recreational activities including those for structured (e.g., sports) & unstructured (e.g., play) activities important**
- Facilities that supported children's play (e.g., playgrounds, trees for climbing) also important
- **Importance of accessibility for encouraging park use among children regardless of gender, ethnicity & socioeconomic status**
- **Constructed and natural trails important among adolescent girls**

#### Lee and Maheswaran (2011) REVIEW

- Reviewed 35 articles
- Green spaces may influence social capital by providing meeting place for users to develop & maintain neighborhood social ties
- Social interaction enhances personal & social communication skills of users & presence of green vegetation & formation of neighborhood social ties in urban areas significantly contributes to residents' sense of safety and adjustment

#### Coon et al. (2011) REVIEW

- Reviewed 11 articles, 833 adults w/13 different outcome measures used to evaluate effects of exercise on mental well-being & four outcome measures used to assess attitude to exercise; all included studies measured effects of participating in physical activity on measures of mental well-being shortly following activity (most common mental well-being outcome some measure of an individual's mood or feelings); most studies conducted on University campuses in United States
- Seven studies showed measures of revitalization, self-esteem, positive engagement & subjective vitality all greater following outdoor walking as were feelings of energy, pleasure & delight & there were decreases in feelings of frustration, worry, confusion, depression, tension & tiredness (Peacock et al., 2007; Plante et al., 2003; Plante et al., 2006; Plante et al., 2007; Focht 2009; Teas et al., 2007; Ryan et al., 2010)

#### Zhou and Rana (2012) REVIEW

- Urban green spaces provide distinct senses of colors, shapes, textures & sounds & these senses vary as consequence of change of seasons, weather, or time of day

- Sense of beauty derived from urban green space associated w/each individual & many empirical studies indicate that urban green spaces provide great esthetic enjoyments to residents
- Not always limited to visual experience -immersed in some light scent emitted from certain vegetation is pleasant experience
- Sounds from rustling leaves & whistling wind in green space create sense of peacefulness & as city becomes more & more dense, elaborate & ingenious design of urban green corridor can add beautiful elements to each citizen's life
- **Green space improves self-discipline, lowers rate of truancy & allows for even better scholar achievement in children**
- Kweon et al., (1998) note **older people in inner city w/greater accessibility to green space have more social ties than others**
- Sugiyama et al., (2009) found that green space particularly important to maintain & enhance quality of life of older people
- Sugiyama & Thompson (2007) found that **walkable green space elongates age of senior citizens regardless of their sex, marital status & socioeconomic status & sleeping ability** which troubles many old people can be largely improved

Lachowycz and Jones (2013) REVIEW

- **Social meaning attached to greenspace & social perceptions of accessibility may be far more important drivers of health than merely having physical access**

Keniger et al. (2013) REVIEW

- Reviewed 57 peer-reviewed scientific literature prior to June 2011
- Fuller et al., (2007) compared 15 urban green spaces & found that restorative benefits to park users, as measured by self-report ability to reflect (a dimension of Attention Restoration Theory), increased w/plant species richness in green spaces which highlights importance of considering biological diversity & complexity when investigating benefits of interacting w/nature
- Evidence that childhood interactions w/nature may influence attitudes towards nature in later life & while not necessarily a benefit per se, there is much interest from sustainability perspective in how attitudes & behaviors that are positive toward nature develop

Lovell et al. (2014) REVIEW

- Reviewed 17 published between January 1980 & December 2012 from any country
- Luck et al., (2011) found that both personal well-being & neighborhood satisfaction (termed “neighborhood well-being”) increased in relation to greater species richness & abundance & w/increased vegetative cover & density (assessed using standardized ecological surveys)
- Dallimer et al., (2012) & Fuller et al., (2007) found that bird species richness positively associated w/measures of well-being & Fuller et al., (2007) found that enhanced well-being related to increased plant species richness
- Curtin (2009) concluded “sharing our world w/abundant flora & fauna enhanced day-to-day well-being & happiness which has significant psychological & other health benefits”

Berto (2014) REVIEW

- Research has shown that natural settings might have restorative effects that include increased performance on task requiring attention & cognitive processing & cognitive restoration following

visual exposure to natural environment, as reflected in improved performance on attentional tasks, has been established in variety of experimental studies

#### Hartig et al. (2014) REVIEW

- Reviewed 59 articles (only "review" articles)
- Natural features may lead people to favor walking or cycling over other transport modes by making routes to destinations more attractive; however, **distance to destination, availability of suitable infrastructure (e.g., sidewalks, bicycle paths), and safety are more important factors**
- Overall impact of vegetation on air quality is a function of several processes, operating in opposing directions: hydrocarbon emissions, pollen production, pollutant uptake, and effects on energy demand
- Careful selection of species, design of planting configurations with regard to wind, shade, and other impacts, and maintenance of urban vegetation can optimize the beneficial effects on air quality

#### Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using key words “child\*,” “youth,” “young people,” or “adolescents” in combination with “health” or “well-being” and “natural environment,” “green space,” or “parks”; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); ethnographic work on children in nature in the 1970s and later years was gathered through the author’s participation in the development of this field
- Confounders adjusted for in articles included air pollution, noise, temperature where confounders noted in the section on physical health
- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety
- Studies in the United States and Europe show that **low-income and ethnic minority families have less access to urban green spaces in general or large well-maintained parks w/amenities in particular**

#### Shanahan, Lin, et al. (2015) REVIEW

- Most significant body of research to date shows strong positive correlation between exposure to nature & psychological well-being measured in range of ways, including mental restoration, self-esteem, attachment & anger, cognitive function (commonly assessed using measures of attention), systolic & diastolic blood pressure & heart rate & recovery/healing times
- Well-being responses like **relief from mental fatigue & subsequent feelings of restoration from exposure to nature can be immediately elicited on exposure to nature** (i.e., acute response) & as consequence may only be measurable in immediate short term
- Evidence suggests very rapid improvement in psychological well-being possible in response to very low durations of nature dose, after which rate of response could either plateau or decline e.g., cognitive function found to improve after <10 minutes of viewing photographs of natural settings & rapid responses to natural environments identified w/in studies that examine effects of glimpses of nature from window at home; these have been correlated w/improved feelings of life satisfaction & well-being (Kaplan 2001)

#### Rakhshandehroo et al. (2015) REVIEW

- Urban open green spaces combine ecology w/social scope, allowing people to meet & interact to establish relationships & to develop social ties w/in local communities & can contribute to social justice by creating opportunities for all people to participate in close interaction between social layers of diverse ethnic & racial backgrounds
- Studies stated vegetation can reduce fear of crime (Taylor, Kuo, & Sullivan, 2002) or incidences of crime & anti-social behavior (Kuo & Sullivan, 2001)
- **Green space provides children w/range of sensory experiences & helps them refine motor skills, achieve social development & practice social skills** (Gilliland, Holmes, Irwin & Tucker, 2006; Gearin & Kahle, 2006)

Capaldi et al. (2015) REVIEW

- Mayer et al., (2009) found participants who were randomly assigned to take walk in nature reported significantly reduced public self-awareness
- Adults who had spent time in wilderness reported that what made their experiences especially meaningful was fact that “there was virtually no reason to be anyone but themselves” (Fredrickson & Anderson, 1999)
- Experience of vitality—fully feeling alive & energized (Ryan & Frederick, 1997) —appears to be enhanced by connecting w/nature
- **Elevating feelings of awe & inspiration, connection to greater whole & spiritual exaltation—** transcendent aspects of eudaimonic well-being—have been linked w/nature
- **Sights & sounds of nature are some of most common elicitors of awe, particularly fractal patterns found in trees, clouds, rain & birdsongs** (Forsythe & Sheehy 2011; Richards 2001)
- Trait nature connectedness positively associated w/humanitarianism (Nisbet et al., 2009), social well-being (Howell, Dopko, Passmore, & Buro, 2011; Howell, Passmore, & Buro, 2013), kindness (Leary et al., 2008), empathic concern (Zhang, Piff, Iyer, Koleva, & Keltner, 2014), altruistic concern (Schultz, 2001) & perspective taking (Schultz, 2001)

Christian et al. (2015) REVIEW

- Reviewed 32 studies, mostly conducted in USA, Australia & Europe w/over two thirds (69%) examining behaviors (e.g., outdoor play & physical activity) through which children develop social-emotional competence, language & communication skills, rather than domains of early child development per se
- In young children, amount of outdoor play as well as time spent outside unaccompanied at front of house or on street negatively associated w/street traffic (Hüttenmoser, 1995, Aarts et al., 2012)
- Large **US study of 22,797 children 1–5 years found that limited perceived access to amenities** (recreation/community center, library, sidewalks, **park**/playground) **associated w/less time spent in peer play & fewer family outings** (Kenney, 2012)

Webster (2015) REVIEW

- 1) subjective measurements (e.g., subjects are asked how happy they feel); An example of a better option is to use remote sensing data; 2) over-reliance on case study designs; 3) small “n” (a larger n is needed to control for confounding); 4) lack of longitudinal studies; 5) lack of individual effects analysis; 6) accessibility to green space measured with crude estimates/ecological fallacy - using a network is better; 7) arbitrary spatial scale

D'Alessandro et al. (2015) REVIEW



- Results section indicates search but then different article cited; number of citations do not match up with references: “A «web of knowledge» search with just two terms, «green space and health», yielded 2 hits for 1990-1999, 34 for 2000-2009, and 45 from 2010 to June 2013; in the same paper; authors performed a «review of reviews» on the topic until April 2013, involving 56 relevant reviews 2009, and 45 from 2010 to June 2013”
- Trees improve air quality indirectly when they cool urban environments and reduce building energy demand
- Positive relationship between social cohesion and natural environments

#### Eisenman (2016) REVIEW

- Reviewed studies addressing links between green space and antisocial outcomes focus largely on crime-related activity, fear, and interpersonal aggression; Pathways between green space and health: air quality, physical activity, social cohesion, and stress reduction
- Pioneering site-scale studies in Chicago public housing developments showed systematically more violent crimes at buildings with the least vegetation, and higher levels of household aggression and violence among residents in buildings with views onto concrete and asphalt than counterparts living in identical buildings with views of trees
- Cleaning and greening over 4,400 vacant lots in Philadelphia associated with consistent reductions in gun assaults; Prosocial outcomes: three individuals living next to greener common spaces had more neighborhood social ties (NSTs), characterized by more social activities and visitors, knowing more neighbors, more concern with helping and supporting one another, and stronger feelings of belonging
- Studies with statistical tests of mediating processes indicated that greater use of green spaces explained the link to NSTs, which have been linked to lower risk of stroke, chronic health impairments, and emotional distress
- Early studies showed that people associate dense, unmaintained vegetation with feelings of reduced security, and fear of crime, by blocking views and providing a hiding place for criminals which supported urban crime control strategies to remove vegetation
- Subsequent research suggests that well-maintained greenery can have an opposite influence by deterring criminal activity

#### Jennings et al. (2016) REVIEW

- Many recent studies reveal that accessible neighborhood green space can promote social cohesion and social relationships; Studies observed link between coverage of green spaces & social indicators like neighborhood satisfaction in Flint, Michigan, Baltimore, Maryland, & central Ohio (Alaimo et al., 2010; Holtan et al., 2015; Hur et al., 2010); Green spaces may also enhance sense of place & place attachment by increasing neighborhood satisfaction
- Florida et al., (2010) used survey data to examine influence of aesthetic beauty on community satisfaction across US, found **significant positive relationship between attractive physical settings (e.g., trails, outdoor parks & playgrounds) & community satisfaction**; encouraging social interactions across diverse populations, green spaces such as public **parks can potentially remedy documented decline of social relationships in urban areas**
- Fan et al., (2011) used survey data to examine role of neighborhood green spaces on social support in Chicago, found parks can foster social support & indirectly mitigate stress, also recreation & cultural activities on neighborhood green spaces provide an opportunity for residents to interact w/others outside of family

- Larson et al., (2013) found many parents recognized diverse physical, mental & social health benefits associated with their children’s outdoor recreation experiences in Georgia state parks, particularly when these experiences involved bonding interactions with family and friends
- Wu et al., (2014) examined relationship between academic performance & surrounding greenness among elementary schools in Massachusetts, after adjusting for confounding variables (e.g., income levels, English not being students’ first language, attendance, gender & levels of urbanization), determined that higher levels of greenness associated w/higher student performance in English & math
- Other research observed similar positive links between nearby green space & student performance among high school students in Michigan & school-aged children in New England

MacBride-Stewart et al. (2016) REVIEW

- While green space can be beneficial for health, research has suggested that women are more susceptible to the effects of environmental degradation in the local environment than men

O Douglas et al. (2017) REVIEW

- Cross-sectional research supports association between increased greenness & range of improved cardiovascular outcomes in adults
- Grahn and Stigsdotter (2010) found relationship between sensory perception of natural environments & human health in that adults identified preference for ‘serene’ green space, followed by increased ‘space’, ‘nature’, ‘species richness’, ‘refuge’, ‘culture’, ‘prospect’ & ‘social’ dimensions while dimensions of ‘refuge’ & ‘nature’ found to be most strongly correlated w/stress, suggesting that stressed individuals may seek out most restorative environments
- Jakubec et al., (2016) identified positive trend towards improved depression markers, greater health satisfaction, improved social relationships (in particular, love & friendship) & satisfaction w/sense of community & experiences of helping among adults w/disabilities & caregivers as result of direct exposure to nature & green space
- **Strong relationship between frequent childhood visits to green space & being prepared to visit such places alone as an adult**
- Kytta et al., (2012) identified 10–15 year olds more likely to report they had very good health when there was significant green space around their home, after controlling for neighborhood socio-economic status
- Kweon, Sullivan, and Wiley (1998) investigated relationship between older adults' exposure to nearby public green spaces & level of social integration & attachment to local community; Study determined correlations between use of public green space & strength of neighborhood social ties & sense of community; for older adult residents of inner-city deaths have been recorded in areas characterized by low greenness & increased exposure to greenness proximate to neighborhoods

McCormick (2017) REVIEW

- Reviewed 12 articles
- Data from 905 Massachusetts public schools collected between 2006 and 2012 revealing consistent positive association between “greenness” of schools and performance in English and Math on standardized tests (Wu et al., 2014)

L Nesbitt et al. (2017) REVIEW

- Reviewed 38 studies focused on North America that examined the services of mixed vegetation (i.e., multiple or unspecified types of vegetation), 31 studies that examined the services of trees, and 43 studies that examined the services of green spaces
- Green spaces offer residents opportunities to play and recover from sometimes stressful urban environments & in this context, **recreational, aesthetic & cultural benefits of green spaces may well be highest-valued ecosystem services in cities** (Bolund and Hunhammer, 1999)
- **Urban greenery can also help residents develop sense of community and neighborhood attachment, increase social contacts, and reduce feelings of social isolation**

Nieuwenhuijsen et al. (2017) REVIEW

- Newly promoted biodiversity hypothesis suggests that **reduced contact w/nature may adversely affect human commensal microbiota & its immunomodulatory capacity**
- Hanski et al., (2012) found relationship between generic composition of skin microbiota & land use type around home; also found reduced level of allergic disease, mediated through acinetobacter & gammaproteobacteria, but few studies so far have focused on this mechanism
- De Vries et al., (2013) estimated contribution of different potential mediators of green space on health (stress, social cohesion, green physical activity) to general health, acute complaints & mental health & found that stress & social cohesion contributed most to outcomes (around 20%-40%), while green physical activity contributed less than 10%

Reid, Clougherty, Shmool, and ... (2017) ORIGINAL RESEARCH

- Study based in New York City, NY, USA w/1281 participants using 2010 High Resolution Land Cover dataset for New York City (NYC) to estimate association between near-residence trees, grass & total vegetation; 300 m & 1000 m buffers; self-reported health measure was single validated item drawn from NYC Department of Health & Mental Hygiene Community Health Survey (“Would you say that in general your health is excellent, very good, good, fair or poor?”); 2nd model adjusted for age, sex, race/ethnicity, sampling frame, season, neighborhood tenure, individual-level SES (income, educational attainment) & area-level SES [percent living below two times federal poverty level (FPL) & percent unemployed at census tract]; 3rd model adjusted for nitrogen dioxide; 4th model further adjusted for percent park and percent non-park open spaces; near-residence trees, grass & total vegetation; calculated percent city-designated park area using NYC Department of Parks & Recreation Parks Properties shapefile & percent non-park open space using NYC Open Space (not parks) shapefile w/in each radial buffer
- Higher tree density w/1000 m associated w/higher likelihood of reporting “very good” or “excellent” health comparing highest quartile to lowest quartile relative risk (RR) = 1.23, 95% CI = (1.06, 1.44) adjusted for individual-level & area-level SES; at 1000 m buffer, higher tree density associated w/better self-reported health among individuals w/higher income/higher education & w/lower income/lower education; no apparent association between trees or grass w/in 300 m buffers in self-reported health for any SES category
- Exposure to trees & to lesser extent grass showed positive associations w/better self-reported health when holding exposure to parks & open spaces constant

Buckley and Brough (2017) REVIEW

- Reviewed articles focused in Australia but applicable to other locations with appropriate data; included park use patterns, mental health outcomes, and economic values
- Sources of data include: Big data (e.g., national datasets) in three major categories; 1) Park use patterns in three broad categories [(i) brief visits to natural environments in residential areas,

variously known as neighborhood nature, metro nature, or urban greenspace; (ii) single-day visits to parks and other public lands allocated for conservation and/or recreation; and (iii) multi-day programs]; 2) Principal types of mental health outcomes reported in previous studies include: improved attention, changed attitudes, improved cognition, reduced stress, anxiety, depression, reduced use of anti-depressants, improved recovery from stress, general improvements in mental health, improved sleep, improved general life satisfaction; 3) Involves the estimation of economic values of mental health outcomes through multiple parallel additive pathways

- Individual humans value their own health and happiness much more highly than the natural environment & government budget allocations for public health are far higher than those for conservation

#### Bosch and Sang (2017) REVIEW

- Reviewed 13 total peer-reviewed articles written in English found in April 2016 ("only 3 of those were retrieved if including health in the search terms")
- Dzhambov & Dimitrova (2014) reviewed effect of green spaces on negative health impacts of noise (only 5 studies) & concluded that there is moderate evidence that **presence of vegetation can reduce negative perception of noise**
- van den Berg et al., (2015) concluded that there is moderate to strong evidence for **positive association between green spaces & all-cause mortality**
- Gascon et al., (2016) found moderate to strong evidence for association between natural environments & CVD-mortality

#### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles; restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Kawachi & Berkman (2001) indicated potential to be outside in green space to increase older people's health
- Arnberger et al., (2017) found that elderly prefer to visit nearby green spaces that provide shade, water (e.g., ponds) & cooler environment than their homes
- Sugiyama & Thompson (2007) have demonstrated that neighborhood environments likely to contribute to health of elderly by providing opportunity spaces for being active

#### Parker and Simpson (2018) REVIEW

- Reviewed 87 total, 71 on public green infrastructure (PGI) & 16 articles added for an update in May 2018; highest number of articles from Australia but many countries were included
- Articles reviewed identified six attributes of PGI spaces that are reported by the PGI-livability literature as contributing to improved livability of urbanized landscapes in order of decreasing frequency of reporting; those attributes are quality of PGI spaces, opportunities that PGI space provide to experience the natural environmental and ecological processes, presence of PGI spaces in the urban fabric, ease of access to PGI spaces (in terms of both availability and location of PGI spaces and PGI spaces being equitably—socially and physically—accessible all community members), internal walkability of PGI spaces, and presence of tree canopy cover at PGI sites

#### Fong et al. (2018) REVIEW

- Reviewed articles published January 2015 to October 2017

- James et al., (2016) conducted prospective cohort study analyzing data from 108,630 female nurses in US followed for 627,008 person-years from 2000–2008 & found that per 0.1 NDVI increase, their mortality was 12% (95% CI: 6, 18) lower but strongest findings were for cancer & respiratory mortality & mediation analyses suggested that mental health pathway explained 30% of association
- For most mortality outcomes, associations stronger in urban communities, among younger individuals & in women & highest SES individuals
- Kondo et al., (2017) investigated whether being near urban tree cover during outdoor activities was related to gun assaults; 135 patients interviewed who had been shot w/firearm & 274 community controls in Philadelphia, PA from 2008–2011, case times (when assaults happened) compared to control times matched for time of day, **having been under tree cover inversely associated w/gunshot assault** (OR 0.70, 95% CI: 0.55, 0.88), especially in low-income areas (OR 0.69, 95% CI: 0.54, 0.87)
- MacNaughton et al., (2017) study used ecological approach in Massachusetts w/greenness around schools as exposure & chronic absenteeism as outcome, defined as % of students missing 10% or more of total school days in year & found an IQR (0.15) increase in NDVI associated w/2.6% decrease in chronic school absenteeism

#### C. Twohig-Bennett and A. Jones (2018) REVIEW

- Reviewed 143 total articles (n=103 observational, n=40 interventional) investigating ~100 health outcomes until January 2017 & published in English; combined population size of > 290 million in 143 different studies analyzed
- Two studies reporting on cancer outcomes & found that living in highest quartile of greenspace associated w/significantly reduced risk of prostate cancer (Demoury et al., 2017), OR 0.82 (95% CI 0.72, 0.92) & reduced incidence of overall cancer mortality HR 0.87 (95% CI 0.78, 0.97) (James et al., 2016)
- Meta-analysis results showed increased greenspace exposure associated w/increased incidence of good self-reported health 1.12 (95% CI 1.05, 1.19); **exposure to diverse variety of bacteria present in natural areas may convey immunoregulatory benefits & reduce inflammation** (Rook, 2013)
- Much of literature on forest bathing suggests that phytoncides (volatile organic compounds w/antibacterial properties) released by trees may explain salutogenic properties of shinrin yoku (Li et al., 2009, Tsunetsugu et al., 2010)

#### Kondo et al. (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- Demoury et al., (2017) examined whether residential green space exposure related to prostate cancer incidence using population-based case-control study & when controlling for individual factors (demographic background; family & medical history; smoking, alcohol, diet & physical activity-related behaviors) they found that **increased residential greenness associated w/lower risk of cancer**
- Crouse et al., (2017) conducted large cohort study of mortality among non-immigrant Canadians residing in 30 cities between 2001 & 2011 & using annual measurements of residential green space, they found protective association w/non-accidental, cardiovascular (plus diabetes), cardiovascular, ischemic heart disease, cerebrovascular & respiratory mortality & finding that sex, age, income, educational attainment & marriage status modified estimates
- Richardson et al., (2017) conducted longitudinal cohort study of children between 2005 & 2010 w/participants approximately one year old at recruitment & using Strength & Difficulties

Questionnaire & controlling for many individual, family & neighborhood factors found that increasing exposure to green space (measured as % green space & parks w/in ward of residence) associated w/improved social outcomes

#### Mygind et al. (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included 1 or more controlled studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight w/in-subjects designs); Participants predominantly 11-18 years ( $\approx 80\%$ ) &  $\sim 10\%$  of identified studies included participants  $< 11$  (3–7 years  $\approx 3\%$ , 7–11 years  $\approx 7\%$ ) & children & adolescents w/behavioral and/or emotional disturbances (e.g. attention deficit hyperactivity disorder (ADHD) or depression), substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Dettweiler et al., (2017) found cortisol levels decreased over one day of education outside classroom but quality of evidence considered low due to bias and imprecision from small sample size
- Childhood mental, physical & social well-being & lifestyle have been associated w/late-life behaviors, function & well-being so health promotion & prevention targeting children has never been more pertinent
- American Institutes for Research (2005) found that problem solving improved upon 5-day outdoor science school program & reported that at-risk & underachieving participants' academic performances improved following 5-day outdoor science school program
- Mygind et al., (2009) found primary school pupils reported improved levels of social relations, for example, levels of teasing & quarrelling, influence on play & helping behaviors, when participating in education outside classroom in natural environments compared to classroom-based teaching
- Two individual studies from Hayhurst et al., (2015) including different populations reported improvements in resilience amongst high school students following 10-day voyage but quality of evidence considered low; Gillespie & Allen-Craig (2009) amongst 14-16 year-old males described as at-risk, resilience was increased over course of 5-week residential wilderness therapy
- Sproule et al., (2013) reported increase in 13 year-old pupils' problem solving competences pre- to post-12-day outdoor education program & Gillespie and Allen-Craig (2009) found 14-16 year-old males' problem solving increased over course of 5-week residential wilderness therapy
- Harper et al., (2007) found academic performance of 13–18 year-old males but not females w/emotional & behavioral challenges increased from pre- to post-21 days of wilderness therapy
- Norton & Watt (2014) found under-resourced urban adolescents aged 13 to 18 reported improvements in family support over course of 7- to 8-day expedition
- Ee & Ong (2014) found secondary pupils aged on average 14.1 years old reported that their social awareness, self-management & relationship management improved over course of 2-day camp

#### CR Hall and MJ Knuth (2019b) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Design of park, its location & people's image of park in combination w/cultural characteristics of various ethnic groups inform opportunities for intercultural interactions leading to social cohesion (Peters et al. 2010); **access to nature is significant predictor of several happiness indicators, even after controlling for other connections** (Zelenski and Nisbet 2014) & results support notion that

nature relatedness could be path to human happiness & environmental sustainability (Despard 2016, Glover et al. 2005)

- As children's direct connection to neighborhood biodiversity progressively declines, it can have serious implications for public health & biodiversity conservation at community level
- Rich multi-sensory experience of being outdoors encourages children to be more observant of & curious about their surroundings, leading to desire to explore, investigate & make sense of their observations
- Symbolic play, in which children allow one thing to represent another or in which they take on roles & allow themselves to represent another persona, considered an important element in development of abstract thinking (Kemple et al. 2016)

#### CR Hall and MJ Knuth (2019a) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Multiple studies have reported **allergies, asthma & eczema (which all reflect hypersensitivity of immune system) less prevalent among persons w/greener residential surroundings** (Fuertes et al. 2014, Hanski et al. 2012, Lovasi et al. 2008, Maas et al. 2009, Ruokolainen et al. 2015)
- Multiple authors have found that attention restoration, state changes in cognitive functioning & recovery from ego-depletion influenced by same underlying green space mechanisms (Hofmann et al. 2012, Kaplan and Kaplan 1989, Kaplan and Berman 2010, Ryan et al. 2010)

#### Hunter et al. (2019) REVIEW

- Reviewed 39 studies from high income countries (e.g., US, United Kingdom, Australia)
- Overall, 68% (n=26/38) of studies found a significant positive intervention effect to support the provision of urban green space interventions for health, well-being, social and environmental effects
- All studies of park-based interventions (n=7/7 studies) that used a dual approach (i.e. physical change to UGS and promotion/marketing programs) showed significant intervention effect
- Five of these seven studies showed significantly positive post-intervention effect for increasing park usage and physical activity following: major improvements to playing fields of public parks
- All studies of greenways and trails (n=3/3 studies) that employed dual approach (i.e. combined change to the physical environment of greenway or trail with promotion/marketing programs) showed significant intervention effect
- All studies (n=4/4 studies) showed significant intervention effect to support the greening of vacant lots for improved physiological, psychological, safety and biodiversity
- Positive effects for increasing park usage, quality of life and the perception of safety following improved footpaths and clearing of rubbish and vandalism (Ward Thompson et al., 2013)

#### Lai et al. (2019) REVIEW

- Reviewed 275 studies
- Several review papers have hypothesized that exposure to microbial biodiversity may benefit immunoregulatory functions (Rook 2013; Rook et al. 2014) & that **transmission of pathogens may occur less rapidly in biologically complex green areas** (Rook et al. 2014)

#### Saitta et al. (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016

- **Park environment provided opportunities for developing creativity & imagination, increasing concentration span & self-esteem, self-efficacy, confidence & sense of accomplishment** (Jeanes & Magee 2012; Nakau et al., 2013; Ripat & Becker 2012)
- In addition to decreasing loneliness, participants reported that accessible, usable & inclusive parks enabled social interaction & development of social skills but was also suggested that **parks could provide environment to expose people w/out disability to persons w/disability & this fostered community learning** (Chow 2013; Finlay et al., 2015, Jeanes & Magee 2012; Ripat & Becker 2012), **improved acceptance/tolerance w/in society while empowering social confidence of persons w/disabilities** but not all parks perceived to be accessible or usable & **some parks prevented inclusion making participants feel unwelcome which resulted in inequity & inequality** (Finlay et al., 2015, Jeanes & Magee 2012; Ripat & Becker 2012)
- Some evidence to suggest that accessible parks could foster integration & social inclusion (Jeanes & Magee 2012; Ripat & Becker 2012)
- Play can be even more effective for development of social skills in children w/autism, intellectual, physical & sensory disabilities & for children w/low social skills
- **Accessible parks could minimize loneliness & boredom** (Chow 2013; Finlay et al., 2015); Gardner (2014) found that in park use by older adults, **psychological & social benefits of parks, not physical, were of primary importance to older adults in general population** & that any engagement in physical activity in park was predominantly incidental
- Results on psychological & social benefits important finding given that over 45% of older adults report being lonely

#### Kruize et al. (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Another suggested immunological pathway is through **exposure to diverse microorganisms in green space which can play immunoregulatory role** & Hanski et al., (2012) found in 118 adolescents in eastern Finland that, compared w/healthy individuals, atopic individuals had lower environmental biodiversity in surroundings of their homes & significantly lower generic diversity of gammaproteobacteria on their skin, that help to prevent people from having allergic reactions so these results raise fundamental questions about consequences of biodiversity loss for both allergic conditions & population health in general
- **Public urban green space plays important role in children's & young people's social networks including friendships across cultures & promoting social inclusion**
- Being nature oriented & having positive childhood experiences of nature motivate green space use which emphasizes importance of bringing children into contact w/nature
- Older people derive considerable pleasure & enjoyment from viewing & being in nature which has positive impact on their well-being & quality of life & those living in inner-city neighborhoods benefit from presence & use of green spaces which promotes social ties & sense of community
- Older people are important target group because **access to green space provides activities that keep them physically active, provide social contacts, help to structure their day-to-day lives & improve quality of life in general & for people w/mental health problems, it may reduce symptoms like depression, anxiety & stress & increase self-esteem**

#### Mmako et al. (2020) REVIEW

- Reviewed 19 articles from high income countries
- Studies showed strong connection between memory stimulation, triggered by the outdoor environment & maintenance of a person's identity [e.g., outdoor environment acted as a means to



recall past life (Ward et al., 2018), make sense of one's place in the present and past (Odzakovic et al., 2018) & support selfhood and well-being (Smith-Carrier et al., 2019)]

#### Grilli and Sacchelli (2020) REVIEW

- Reviewed 36 articles
- White et al., (2019) focused in England found that spending 120 minutes per week in nature sufficient to maintain good health & well-being levels

#### Wolf et al. (2020) REVIEW

- Reviewed 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults & 13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults; 201 total articles sorted into 3-part framework (Reducing Harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; Restoring Capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; Building Capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants; Controlling for socio-economic factors common among cross-sectional studies
- Martínez-Soto et al., (2013) used **fMRI scans** (rather than self-reported data) to **show that forest settings prompted brain area activations related to involuntary attention, a theoretical precursor of cognitive restoration**
- Takayama et al., (2014) found that short sessions (**15 minutes**) of **'forest bathing' produced enhanced subjective feelings of vigor, recovery & vitality**
- Wolf et al., (2017) found that **greater species richness may support mental well-being more than natural environments low in biodiversity** & even natural environments w/low biodiversity may induce more positive affect than built environments
- Small sample experiments of shinrin-yoku have compared health outcomes from experiences of forest versus urban settings, finding reduced prefrontal cerebral activity (Park et al., 2007), lower salivary cortisol levels (an indicator of stress) (Yamaguchi et al., 2006) & suppressed sympathetic nervous activity (i.e., fight or flight response) accompanied by enhanced parasympathetic nervous activity (i.e., rest & digest state) (Tsunetsugu et al., 2007)
- **Increased NK activity can last 7+ days after forest trip** (Li et al., 2008; Li et al., 2008b; Li et al., 2010); Li et al., (2009) suggest that higher concentrations of phytoncides (aromatic VOCs released by trees) typically found in forest settings may contribute to increased NK activity
- Piff et al., (2015) found that **participants staring up at large trees for 1 minute were significantly more likely to perform prosocial helping behaviors** than control group who stared up at large buildings
- Hauru et al., (2012) studied views of urban settings from inside a forest, finding **higher perceived restorativeness when urban settings less visible**

#### Browning and Locke (2020) ORIGINAL RESEARCH

- Study in Maryland, US using Chesapeake Conservancy land dataset [(1) tree cover, (2) herbaceous/low vegetation & shrub cover (hereafter, "grass cover") & (3) total vegetation cover] & 4) & 5) derived from red & infrared wavelengths that were transformed into normalized difference vegetative index values; Point data for schools retrieved from Maryland GIS Data Catalog; attendance areas retrieved from National Center for Education Statistics; school parcel polygons accessed via

Maryland Property View; math & reading test scores from 2016 retrieved from Maryland School Report Cards; Racial, ethnic & gender composition of students & student-to-teacher ratios obtained from National Center for Education Statistics; total of 668 public schools, 8-9 year olds (3rd grade) student test scores from 2015-2016; greenspace measures calculated in two zones: 1) around school + 25 m buffer & 2) in school attendance boundaries + 25 m buffer

- Controlled for random effects attributable to broader social, geographic & environmental context of United States county where each school located
- Multivariate regression models revealed positive associations between academic performance & low-resolution NDVI measures around schools & in neighborhoods & between performance & tree cover in neighborhoods
- Bivariate correlations suggested all measures of greenspace positively & significantly related to math & reading test scores ( $p < 0.05$ ); 250 m<sup>2</sup> NDVI positively & significantly associated w/reading & math scores in school zones & neighborhood zones
- Tree cover in school zones & grass cover in neighborhood zones positively associated w/reading scores
- Only two interaction terms statistically significant in models w/neighborhood zone greenspace measures: 30 m<sup>2</sup> NDVI in math models & 30 m<sup>2</sup> NDVI in reading models
- Coarse-resolution greenness measures predicted academic performance in initial models but these associations disappeared when urbanicity was controlled for
- Direct exposure shows beneficial effects on working memory, cognitive flexibility & attentional control (Stevenson et al., 2018) & emotional regulation & time-on-task in classrooms (Kuo et al., 2018)
- Students who spent more time in forested landscapes during childhood earned higher grades in college (Spero et al., 2018)

Hartley et al. (2020) REVIEW

- Reviewed 7 articles; 6/7 studies used NDVI
- Three papers reported **greenness was protective for child asthma via mediation of other negatively related health factors, such as difficult family relationships** (Chen et al., 2017), **high traffic volume** (Feng & Astell-Burt, 2017), **and tobacco smoke exposure** (Eldeirawi et al., 2019)
- **Greenness** has no direct effect on child asthma but **may be protective via modification of individual and community-level risk factors**

**Additional Findings on Health Benefits of Urban Greenspace**





### Additional Findings / Important Points

**Summary:** There are many other research findings not appropriately categorized as measured or perceived mental, physical or social health benefits. Some of these findings are documented below from sixty peer-reviewed articles and include: importance of accessibility and safety of urban green spaces to ensure inclusivity, cultural ecosystem services provided by urban greenspace, and the potential for biodiversity in contributing to health benefits of urban greenspace. Also included here are some of the hypothesized pathways for health benefits and underlying theoretical bases for such hypotheses. One of these theories, the Attention Restoration Theory, suggests that experiences in natural environments can reduce mental fatigue and restore our capability for directed attention (which requires significant mental effort), therefore engaging in the involuntary fascination attention that natural environments provide allows more room for directed attention; this becomes particularly relevant when considering the directed attention demands of fast-paced, modern, urban environments (Beyer et al., 2014; Capaldi et al., 2015; Mennis et al., 2018). The Stress-reduction theory maintains that exposure to certain unthreatening natural environments that were evolutionarily beneficial to our well-being and survival automatically elicits a variety of stress-reducing psychophysiological responses (Capaldi et al., 2015; Mennis et al., 2018), including lower heart rate, skin conductance recovery, and lower concentrations of the stress hormone cortisol (Hall and Knuth, 2019). The biophilia hypothesis assumes that because human beings evolved in natural environments, they developed an innate tendency to respond positively to natural settings; this positive response includes psychological restoration (Carrus et al., 2015). While considering various health benefits of urban greenspace and underlying mechanisms in contributing to them, it is also important to note what has not been studied but of suggested importance, mainly the lack of research studies investigating health inequities and impact of urban nature on disadvantaged and vulnerable populations (Kondo et al., 2018). Note: The type of article is indicated to the right of the reference (i.e., “ORIGINAL RESEARCH” or “REVIEW”).

#### Smardon (1988) REVIEW

- Consistent w/restoration hypothesis, exposure to vegetation views significantly reduced feelings of fear & positive effects such as affection & elation were increased
- Urban vegetation provides different kinds of screening useful in urban environments, one type of screening is to block views to objectionable objects or scenes
- Space definition, privacy control & progressive realization or gradual opening up view of special scene & another form of screening effect of vegetation on blocking or filtering light - especially direct & indirect glare - trees are easier on the eyes; gentle greens, yellows & blues of trees w/their softer-textured leaves that filter & reflect light, making ever-changing patterns, provide much needed contrast to reds, whites & grays, often coarse & barren textures, hard reflections & glare of static, constructed environment
- Trees are primary & sometimes last representatives of nature in city & thus individuals or groups may see trees as anchors of stability in urban scene
- Trees absorb structures & in larger scale have visual absorptive capacity or vegetative opacity for absorbing or dampening impacts of urban development & trees add visual diversity or complexity to urban environment
- Consistent finding on presence of vegetation, especially trees, has positive effects on preference
- Buhyoff et al., (1984) found among most important physical variables in terms of positive relationships w/preference were total area of view depicting vegetation, basal area per tree stem & amount of tree crown enclosure & results suggested street scenes w/small diameter trees may be less preferable than views with larger diameter trees

#### Knecht (2004) REVIEW

- Being in a natural setting, Olmstead wrote, “employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it & thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system” (Olmsted 1865, cited in Ulrich et al. 1991)
- Ulrich 1983 identifies these visual properties as key to an aesthetically pleasing scene (& these attributes are evolutionarily adaptive): 1) Complexity is moderate to high, 2) Complexity has structural properties that establish focal point & other order or patterning is present, 3) Moderate to high level of depth that can be perceived unambiguously, 4) Ground surface texture tends to be homogenous & even & is appraised as conducive to movement, 5) Deflected vista is present, suggesting possibility of further discovery, 6) Appraised threat is negligible or absent
- Urban dwellers might constantly be experiencing low-level stress reactions which impact their physical health, cognitive abilities & behaviors which could be alleviated by exposure to natural scenes (Ulrich et al. 1991)
- Along w/“fascination,” natural areas often provide three other important qualities: 1) sense of being away from daily pressures, 2) compatibility w/person’s desired activities or state-of-mind & 3) sense of being in large & coherent setting (Kaplan 1995)
- Natural elements, especially trees, encourage people to spend more time outside, making them more likely to have accidental face-to-face encounters w/their neighbors that create friendships & other social ties
- Vegetation & social ties affect people’s sense of safety & adjustment & may be important force in creating sense of community (Kuo and Sullivan 1998)
- Aesthetic pleasure may be different in residential context; when looking at photograph people generally imagine themselves into the picture (Kaplan and Kaplan 1989), but when looking out residential window, perhaps people know they will remain in safe, hospitable environment
- Critics point out that 2-dimensional photographic studies privilege aesthetic over almost everything else, while real life is constantly-moving, 3-dimensional experience affected not only by view but also by sound of rippling water, feel of wind on one’s face, smell of flowers & bodily experience of movement

#### Gearin and Kahle (2006) ORIGINAL RESEARCH

- 16 high school seniors (n = 5 girls, n = 11 boys; n = 15 Hispanic, n = 1 Asian-American) & adults in Los Angeles, CA, US; focus group & survey
- Access to green space by urban residents has been shown to afford sense of escape from fast paced urban life & place for solitude and contemplation, especially among residents who often have very little private space to themselves

#### Jorgensen and Gobster (2010) REVIEW

- Reviewed 182 articles
- Virtually no research into impact of biodiversity in green spaces on psychological benefits, including psychological restoration, physical health, or behavior, w/notable exception of Fuller et al., (2007)
- There is no single readily identifiable measure of biodiversity

#### McCormack et al. (2010) REVIEW

- Reviewed 21 articles; focus group interviews most common method of collecting data (68%), then individual interviews (67%), then situ observation (24%), w/six studies including multiple data collection methods (29%); several studies include ethnic groups: African Americans, Native

Americans, and Latino and Hispanics; socioeconomic status levels of participants varied across studies; seven studies included data collection from children or adolescents

- Access to nearby parks and natural settings associated w/improved mental health, positive affect & reduced anxiety, physical health & healthy weight among children
- **Necessity of driving to reach park often deterred use**
- Positive attributes of parks included presence of trees & bushes, gardens, grass, flowers, natural settings & water features, air quality & presence of distinctive smells in parks contributed to park aesthetics
- Gill & Simeoni (1995) identified organized festivals & celebrations in local park as bringing together people from divergent backgrounds, thereby encouraging democratic park use
- Qualitative evidence suggests that **accessibility of parks is important for encouraging park use in most, but not all, cases**
- Features of parks that facilitated unstructured (i.e., paths, trails) physical activity important for encouraging park visits & recent quantitative research suggested that parks w/walking paths & trails visited more often than parks containing sports-related facilities
- Socio-demographic characteristics of ambient neighborhoods can influence how people perceive parks, whether they use them & how they use them
- Constructed and natural trails important for park use mostly among adults
- **Importance of accessibility for encouraging park use among adults regardless of gender, ethnicity & socioeconomic status**

#### Lee and Maheswaran (2011) REVIEW

- Reviewed 35 articles
- People w/very good access to large attractive green space were more likely to use it & users more likely to achieve recommended levels of activity compared w/non-users
- **Presence of barriers such as major roads was an influencing factor in accessing green space**
- Studies of park use also note that ethnic minorities & people with disabilities less likely to use green spaces & one explanation given for these differences was **perception of 'safety'**
- Evidence from 14 studies corroborate interventions as ineffective unless fundamental issues addressed (e.g., pre-existing concerns of risks associated w/walking & cycling)
- Much of research from studies based in American, Australian, Dutch & British settings

#### Coon et al. (2011) REVIEW

- Reviewed 11 articles, 833 adults w/13 different outcome measures used to evaluate effects of exercise on mental well-being & four outcome measures used to assess attitude to exercise; all included studies measured effects of participating in physical activity on measures of mental well-being shortly following activity (most common mental well-being outcome some measure of an individual's mood or feelings); most studies conducted on University campuses in the United States
- Anecdotal evidence suggests long-term adherence to exercise initiatives conducted in outdoor natural environments or urban green spaces may be superior to that of indoor exercise interventions
- Studies included were small with no evidence of sample size calculation to support number of included participants
- Lack of variation in both the type of green space used & in type of exercise performed
- All interventions used single episodes of activity
- Relatively poor methodological quality & subject to bias & confounding

#### Zhou and Rana (2012) REVIEW

- **Maintenance, safety & diversity of green space are major factors that influence urban green spaces as attractive amenities**
- Hard to provide a general standard to compare results of accessibility found in different studies
- More accessible green space is, greater value green space possesses so important to attach accessibility analysis in valuation process

#### Rook (2013) REVIEW

- It is suggested that requirement for microbial input from environment to drive immunoregulation is major component of beneficial effect of green space & neglected ecosystem service that is essential for our well-being
- Urban-rural differences equally obvious in psychiatric disorders
- Another situation leading to loss of exposure to microbial biodiversity is immigration from developing country to high-income urban center; migration leads to rapid loss of 1st three categories of organisms shown in Fig. 2; in such immigrant populations, large increases in autoimmunity, inflammatory bowel disease, depression & allergic disorders
- Tens of thousands of microbial species associated w/rhizosphere (the below ground microbial habitat constituted by plant root systems) & phyllosphere (above ground microbial habitats provided by plants)
- Crucial point is that plants are able to shape microbiota of their rhizospheres so nature of vegetation in green space will directly modulate microbiota present in soil, rhizosphere & phyllosphere & indirectly modulate microbiota available from coexisting animal life
- Good evidence that long-term benefit of exposure to natural environment is 1 component of broad range of effects that fall under umbrella terms hygiene hypothesis or Old Friends mechanism or biodiversity hypothesis & requires prolonged exposures particularly during childhood when much of education of immune system occurs; modern life deprives us of many inputs our immune systems evolved to anticipate, so we are more dependent on microbiota of other people & microbiota of natural environment & green spaces

#### Lachowycz and Jones (2013) REVIEW

- Several studies found associations between green space & health only for certain groups, in particular areas or for particular types of greenspace, suggesting relationships sensitive to specific populations & geographical areas; framework shows physical & mental health outcomes as interacting states & does not attempt to link them to specific mediators
- Mediators as three broad groups: 1) improved perceptions of living environment & satisfaction from “having the park there” (Bedimo-Rung, Mowen, & Cohen, 2005), 2) aesthetic satisfaction & restoration from viewing natural features & use of space for relaxation & 3) physical activities, socialization & to interact w/wildlife
- Research thus far failed to find strong evidence for role of behavior change mechanism – such as using greenspace – in relation to access
- Crawford, Jackson, and Godbey (1991) conceptualized barriers to participation in recreation & leisure activities as three key types of constraint: 1) interpersonal (e.g. psychological factors), 2) intrapersonal (factors related to others such as family & friends) & 3) structural constraints (e.g. lack of opportunity, time & money)
- Authors suggest that moderation occurs by three broad mechanisms → 1) opportunity to use greenspace: individuals have constraints which limit their ability to use greenspace independently of how good their physical access is & these constraints include time limitations & physical constraints such as health-limiting factors; possession of commodities such as private transport may make access

easier & this is related to income, although income level per se is arguably not an important factor if public greenspace is free to use; 2) personal motivation & reasons to use greenspace: greenspace is one of many potential health promoting resources which individuals can use or choose not to & motivations to use are influenced by factors such as personal reasons (e.g. walking dog, bird watching, or cycling through it on route to work), perceptions of environment, composition & lifestyle preferences of family & community & opportunities to access alternative health promoting resources such as gyms & gardens; type of greenspace & facilities available will also affect attraction for particular groups; 3) ease of use: environmental features may influence how practical it is to use greenspace & extreme weather conditions or lack of light require individuals to overcome practical considerations, such as obtain appropriate clothing; other environmental factors may influence use, such as speed of traffic or presence of greenery on routes to park

- **Gender may be especially important for relationships w/greenspace accessibility**, as there is evidence that sex influences perceptions & use of environment & physical activity preferences
- Ethnic differences in environmental influences on health can be due to genuine differences in lifestyle & cultural values, or may arise because groups are, or feel, excluded from certain environments (Lee et al., 2001)
- Lifestyle of the household an important moderator for children, for whom parents act as gatekeeper to their use of environment
- Since people need to travel through neighborhoods to reach greenspace, **factors such as busy roads or derelict housing may deter use** (Bedimo-Rung et al., 2005)
- Studies have documented differences between objective & self-reported measures of access, demonstrating how **concept of accessibility strongly shaped by social & personal variables** (Macintyre, Macdonald, & Ellaway, 2008)

Keniger et al. (2013) REVIEW

- Reviewed 57 peer-reviewed scientific literature prior to June 2011
- Specific effects of biodiversity on cognitive performance remain unknown
- Kerr et al., (2006) found in nationwide survey of US adults currently living in urban areas that growing up in natural environments, or participating in activities such as gardening, visiting parks & taking environmental classes during childhood had strong influence on positive environmental attitudes in adult life which highlights **potential for long-term effects of experiences w/nature during childhood**

A. Dzhambov and D. Dimitrova (2014) REVIEW

- Reviewed 24 studies & reduced to 5 studies included in the review
- Three major ways for **vegetation to reduce noise pollution**: 1) diffraction and reflection of sound waves by plant elements, 2) absorption of sound waves and transformation in mechanical vibrations of the plant elements, & 3) destructive interference of sound wave

Haluza et al. (2014) REVIEW

- Reviewed 17 studies most from Japan; no confounders listed but indicates that the following aspects of studies may have decreased the quality of studies: Factors influencing heterogeneity of outcomes could include low assessment quality, in particular due to participant factors (socio-demographic or disease status), outdoor settings (weather features), type of intervention (components, intensity, timing), and appropriateness of the respective control group and statistical power (small or inadequate)



sample sizes); 20 different physiological parameters reflecting effects of exposure to outdoor nature were derived from the 17 articles reviewed; most studies were on Japanese male students

- Article does a good job of explaining different biases and issues with the current literature
- While they reviewed articles that showed significant positive associations between nature and physiological parameters they also saw inconsistent effects or null results

#### Hartig et al. (2014) REVIEW

- Reviewed 59 articles (only "review" articles)
- One interesting finding was that repeated contact with nature lead to an ongoing process of self-regulation; Such studies recognize that some people learn that natural settings are more likely than other settings to be restorative & over time, they apply this knowledge to better manage adaptive resources such as attentional capacity
- Multiple pathways may be purposefully combined in cultural practices that regularly bring people in contact with nature (e.g., community gardening may promote social contacts during moderate physical activity that also supports restoration from stress associated with work or other demands)

#### Moran et al. (2014) REVIEW

- Reviewed 31 articles
- Qualitative studies highlight **importance of micro-scale environmental characteristics (e.g., quality of sidewalk and presence of benches)**, which might be especially relevant for older adults' physical activity, but which have not been linked consistently to older adults' physical activity in previous quantitative studies

#### Berto (2014) REVIEW

- Exposure to nature is coping strategy which has positive effects on both arousal/activation level & cognitive overload
- **Natural settings tend to have lower levels of arousal properties like complexity, intensity & movement than urban environments** so they should have comparatively restorative influences on stress
- Evolutionary perspective contends that because humans evolved over long period in natural environments, people are to some extent physiologically & perhaps psychologically adapted to natural as opposed to urban settings
- Humans have an unlearned predisposition to pay attention & respond positively to natural content (e.g., vegetation, water) & to configurations characteristic of settings that were favorable to survival during evolution
- Research shows environmental preference affected by people's need to get restoration & environments perceived as natural tend to be more restorative than environments perceived to be urban or artificial
- Attention-drawing quality of natural settings referred to as "soft fascination" & **when nature captures people's attention, executive system that regulates directed attention gets to rest, pessimistic thoughts are blocked & negative emotions replaced by positive ones**
- Urban green makes cities more appealing, gives relief from stressful life & opportunity to recover cognitive resources & restore optimal level of physiological activation & can have positive effects on sense of control, privacy, encouraging personal relationships & physical exercise & offering natural fascinating distractions that promotes positive emotions & mood

- Logical extension of attention restoration theory is that **people deprived of nature will display behaviors caused by weary minds: inhibition is essential to delay & reflection, lacking this capability an individual behaves in less adaptive & appropriate fashion**
- Research using Perceived Restorativeness Scale found that higher restorative value of natural versus urban or artificial settings did not differ w/gender or age but findings unclear about whether active or passive involvement w/nature is preferable for restorative benefits & whether restorative outcomes (both physiological & cognitive) vary w/length of exposure to natural stimuli

Beyer et al. (2014) ORIGINAL RESEARCH

- Study of 2,479 individuals nested in 229 Wisconsin Census Block Groups (2008–2009, 2010 and 2011 cohorts of SHOW, ages 21-74 years); used Normalized Difference Vegetation Index (NDVI); used Survey of the Health of Wisconsin (SHOW) database, an ongoing survey established in 2008, that includes information collected through interviews, physical exams & biospecimens from representative sample of Wisconsin residents
- Adjusted for all individual level (age, gender, race and ethnicity, education, income, marital status, insurance status) & neighborhood level (urbanicity/rurality, population density, education, instability, unemployment, poverty, housing tenure, percent African American, median household income) factors; also models adjusted for length of residence of respondent in neighborhood environment measured
- Outcome measures comprise three scales of 42-item Depression Anxiety and Stress Scales (DASS) instrument indicating symptomology for depression (self-disparaging; dispirited, gloomy, blue; convinced life has no meaning or value; pessimistic about future; unable to experience enjoyment or satisfaction; unable to become interested or involved), anxiety (apprehensive, panicky; trembly, shaky; aware of dryness of mouth, breathing difficulties, pounding of heart, sweatiness of palms; worried about performance and possible loss of control) and stress (over-aroused, tense; unable to relax; touchy, easily upset; irritable; easily startled; nervy, jumpy, fidgety; intolerant of interruption or delay)
- **Increasing neighborhood access to green space could be cost-effective strategy to improving health & reducing health disparities**, as lower socioeconomic status groups have more limited ability to travel beyond local neighborhoods, resulting in increased dependence on local environments for healthy lifestyles & exposures
- Attention Restoration Theory posits that experiences in natural environments can reduce mental fatigue & restore capability for directed attention [employed “when something (does) not of itself attract attention, but when it (is) important to attend nonetheless”], maintaining this focus requires mental effort, which can lead to mental fatigue so in order to recover from mental fatigue, an individual must have opportunity to relax directed attention & 1 way to accomplish this is to engage in another kind of attention—fascination attention—which occurs involuntarily & does not require same mental effort as directed attention
- Scholars argue that natural environments have inherent capacity to fascinate, thereby providing restorative experience that enables recovery from mental fatigue so may be particularly relevant when considering directed attention demands of fast-paced, modern, urban environments
- Mental health conditions such as stress, anxiety & depression can be associated w/myriad of other adverse health conditions, missed days of work & low productivity, indicating benefits of such a strategy could be diverse & numerous
- Results indicate that **difference in depressive symptoms between individual living in environment w/no tree canopy & environment w/100% tree canopy is larger than difference in symptoms associated w/individual who is uninsured compared to individual w/private insurance**; those

from lower income brackets & w/out private health insurance experience greater anxiety, stress & depression, supporting notion that low socioeconomic populations could benefit more from increased exposure to green space; here appears younger adults may currently experience greater need to receive mental health benefits conferred by greener environments

#### Lovell et al. (2014) REVIEW

- Reviewed 17 published between January 1980 & December 2012 from any country
- Overall evidence is inconclusive & fails to identify specific role for biodiversity in promotion of better health
- Cultural ecosystem services defined as “nonmaterial” benefits derived from ecosystems & are related to factors such as promotion of well-being through aesthetics, leisure and & recreation & sense of place
- World Health Organization (WHO) Ottawa Charter (1986) specifically identified conservation of natural resources (including biodiversity) as necessary for promotion of good health; social science studies, biophilia hypothesis (Kellert and Wilson, 1995), attention restoration (Kaplan, 1995) & psychoevolutionary stress reduction theories (Ulrich et al., 1991) were used to describe the potentially innate connection of humans to natural world, indicating that greater exposure results in better health outcomes
- Aesthetics, preferences & connection to or sense of place explained potential benefits in studies that focused on use of natural environment for physical activity or other health behaviors; more functional theories were discussed in epidemiological publications, for instance, greater well-being through access to sufficient natural resources (Pereira et al., 2005; Poudyal et al., 2009; Sieswerda et al., 2001) or negative influence of compromised ecosystem function
- Implicit (& in cases explicit) assumptions that greater biodiversity did support better health & well-being may have introduced bias in number of studies
- This review found relationships most evident at local scale which predominantly focused on links between biodiversity w/in living environment or leisure spaces & self-report well-being, suggest these types of exposure may have more linear and demonstrably positive impacts on health, following immediate encounters or through presumed repeated exposures (e.g., via proximity to residence)
- Lack of robust experimental & controlled designs that could elucidate specificity, strength & direction of relationships
- Appears term “biodiversity” not necessarily used according to its formal, scientific definition outside of biological, ecological & conservation sciences

#### Webster (2015) REVIEW

- Call for stronger evidence based on public health and epidemiology

#### Kabisch et al. (2015) REVIEW

- Reviewed 219 articles published in English between 1 January 2000 & 1 October 2013; 40% of all studies applied questionnaire surveys which included interviews, focus groups, or observations applied followed by analyses using GIS
- Comparison between green space preferences & use in developing & developed countries is difficult because of differences in social & cultural preferences & behaviors
- Distant green space use correlated w/cost of transportation, park entrance fees & access to recreational facilities in sub- or peri-urban areas

- People who can easily access distant green spaces belong to middle- or upper-middle-income groups & people from low-income groups struggle to meet cost of services & prefer to visit areas w/in city that are accessible by public transport

#### Shanahan, Fuller, et al. (2015) REVIEW

- Dose–response approach generally considered useful tool for simplifying complexity & for providing guidance for self-regulating behaviors that enhance health outcomes
- Challenges associated w/defining nature dose largely because can be framed in social context as well as objective reality
- Most significant body of research to date shows strong positive correlation between exposure to nature & psychological well-being measured in range of ways, including mental restoration, self-esteem, attachment & anger, cognitive function (commonly assessed using measures of attention), systolic & diastolic blood pressure & heart rate & recovery/healing times
- Studies on the health–nature connection geographically biased toward North America & Europe so limited direct evidence on how culture influences shape & scale of dose–response relationship; demographic characteristics e.g., age & gender can influence whether person likely to visit park (i.e., frequency & duration of nature dose)
- Person's orientation toward nature has greater influence on park visitation (i.e., nature dose) than proximity of parks to home & personal preferences can influence perceived restorativeness of landscape (i.e., the health response) & perception of biodiversity (such as their estimate of species richness) has been found to have greater correlation w/well-being outcomes than actual measures of biodiversity
- Restoration and well-being benefits of nature may be greatest for individuals experiencing stress or anxiety & influence of nature or green exercise on psychological well-being will be much greater w/more immediate rapid increase for more stressed individuals

#### Rakhshandehroo et al. (2015) REVIEW

- Li et al., (2014) found urban green space provides space for socializing, political discourse & cultural expression; human nature to harbor psychological attachment to beautiful natural objects such as pleasing & calming vegetation
- Green open spaces significant because they are aesthetically valuable to communal domain but value is not easily quantifiable, its significance is frequently downplayed
- Open green space users express differing aesthetic preferences & values for features like diverse vegetation & trees, water, varied terrain & topography
- Well designed & maintained open green spaces define identity of towns & cities, because they offer diversity of land uses & opportunities for wide range of activities

#### Shanahan, Lin, et al. (2015) REVIEW

- Benefits of nature span remarkable breadth of health outcomes w/correlational evidence for reduced all-cause mortality & mortality from cardiovascular disease, improved healing times & self-perceived general health, reduced stress, reduced respiratory illness & allergies, improved self-reported well-being & reduced risk of poor mental health, improved social cohesion & improved cognitive ability
- Studies suggest that **variation in nature itself, not just general levels of provision of green space, has important role in enhancing population health**

- Although public green spaces are accessible to all, only portion of population commonly uses these spaces & visitation strongly influenced by factors such as gender, culture & socioeconomic disadvantage

#### Gascon et al. (2015) REVIEW

- Reviewed 28 articles; most of studies considered to be of fair quality & only two of poor quality; Most studies surrounding greenness measured as percent of green space in specific buffer (from 300 m to 3 km) or at census area unit level (CAU) using a land-cover map & seven studies used NDVI as indicator of surrounding greenness located in buffers of 100 to 800 m; half of studies including adults used General Health Questionnaire (GHQ) (n=10), the Mental Health Inventory (MHI) (n=1) or the Short Form health survey (SF) (n=2) to evaluate general mental health
- Evaluated evidence according to age of targeted study population: (1) exclusively children & (2) adults, which can include population from 15 years onwards, or population irrespective of age & evaluated evidence according to type of exposure assessed: (1) surrounding greenness—amount of greenness—e.g., coming from trees, grass, or bushes-w/in certain distance from residence; (2) access to green spaces—presence of a green space—e.g., parks, forests, or other natural areas-w/in walkable distance from residence; (3) quality of green spaces—e.g., aesthetics, biodiversity, walkability, feeling of safety, type of trees, performance of social activities; & (4) blue spaces (amount, access to & quality)—e.g., lakes, rivers, or coastal water
- **300–400 m is threshold after which use of green spaces starts to quickly decline**
- Individuals from lower socioeconomic positions more susceptible to benefit from living near green areas so if further evidence shows such benefits in individuals at higher risk of suffering from mental health problems, then promotion of green spaces in more deprived areas could be way to reduce existing health inequalities in cities
- Future studies recommended to use NDVI as marker of surrounding greenness

#### Carrus et al. (2015) REVIEW

- Study of four Italian medium-to-large size cities: Bari, Florence, Rome & Padua; Questionnaire including measures of length & frequency of visits, perceived restorativeness & self-reported benefits of visit to green spaces; questionnaire had four parts: 1) open-ended, multiple-choice & Likert-type scale questions on setting experience (length and frequency of visits, crowding), main activity performed (socialization, walking, contemplation, or physical activity) & socio-demographic data, 2) eight items taken from Italian version of Perceived Restorativeness Scale (PRS) measuring restorative properties of settings on 5-step Likert scale (scores range from 0 to 4; Cronbach's alpha value is 0.79, indicating good level of internal consistency & reliability), plus single item measuring preference for settings i.e., “I like this place”; 3) six items derived from Laforteza et al. (2009) measuring psychological & physical benefits experienced in environment on 5-step scale (e.g., “Do you feel psychological benefits while visiting this place?”; “Do you feel physical benefits while visiting this place?”; “Overall, how much visiting this place makes you feel better than before?”; scores range from 0 to 4); study population 569 residents (convenience sample); four different types of green areas selected for study varying in level of biodiversity richness (low vs. high) & location (urban vs. peri-urban) according to 2 × 2 factorial design: 1) urban square with trees (urban location, low biodiversity), 2) urban park (urban location, high biodiversity), 3) pinewood forest plantation (peri-urban location, low biodiversity), 4) peri-urban protected reserve (peri-urban location, high biodiversity)

- Biophilia hypothesis assumes human beings evolved in natural environments & developed an innate tendency to respond positively to natural settings (e.g., Wilson, 1984, Wilson, 1999) & this positive response also includes psychological restoration, as conceived by different authors in terms of stress reduction (Ulrich, 1983) & recovery of directed attention (Kaplan & Kaplan, 1989)
- **Biodiversity emerges as important positive element for those green areas located w/in urban system** & size of effect detected in results small but significant
- Perceived restorativeness plays mediatory role in relation between experience of natural settings (i.e., length of visits, activity performed, higher level of biodiversity) & self-reported benefits

#### Capaldi et al. (2015) REVIEW

- Three major theories address question of why connecting w/nature beneficial to our well-being: biophilia, attention restoration & stress reduction; 1) biophilia hypothesis posits that our ancestors' well-being & survival depended on connecting w/nature (i.e., for finding food & water, navigating & predicting time or future weather conditions, etc., 2) attention restoration theory distinguishes between directed attention used for executive functions & involves prolonged focus & effort) & involuntary attention (which is effortless yet demanding); directed attention is limited resource that becomes fatigued after extended use & when depleted may lead to negative emotional states (e.g., irritability) & declines in cognitive performance; natural environments seem particularly restorative - they provide opportunity to get away, contain fascinating rich stimuli that effortlessly engage our involuntary attention & allow us to act w/out need to constantly monitor our behavior; numerous empirical studies report improvements in concentration, directed attention & emotional functioning after contact w/nature, 3) stress-reduction theory maintains exposure to certain (unthreatening) natural environments that were evolutionarily beneficial for well-being & survival automatically elicits a variety of stress-reducing psychophysiological responses
- Researchers in Japan tested how specific elements of nature, such as wood or sound of running water, influence human stress response
- Several decades of evidence suggests that contact w/nature can lower pulse rates, reduce cortisol levels & improve immune functioning
- Hedonic well-being is referred to as subjective or emotional well-being & consists of high levels of positive emotions, low levels of negative emotions & sense of satisfaction w/one's life
- Eudaimonia involves meaning, autonomy, vitality & feelings of transcendence that represent additional components of mental health beyond merely feeling good & has been described as the functioning well component of well-being
- Experiences in natural environments are important source of meaning for adults of all ages
- **Effect of contact w/nature on well-being does not appear to depend on trait connectedness or gender**

#### Cassarino and Setti (2015) REVIEW

- No systematic method mentioned
- Identifies many potential confounders including education or occupation
- When examining rural vs. urban environments air pollution, diet, vitamin D deficiency etc. are confounders & neighborhood, SES, noise
- Both direct (different exposure to, or interaction with, environmental stimuli) and indirect pathways (socioeconomic and lifestyle dimensions) link the environment with cognitive performance
- Environmental noise may affect cognition both directly, e.g. via perceptual stimulation, and indirectly, for example by influencing cardiovascular health

## Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using the key words “child\*,” “youth,” “young people,” or “adolescents” in combination with “health” or “well-being” and “natural environment,” “green space,” or “parks”; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); ethnographic work on children in nature in the 1970s and later years was gathered through the author’s participation in the development of this field
- Confounders adjusted for in articles included air pollution, noise, temperature where confounders noted in the section on physical health
- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety
- Future research on children, nature, and health will do well to find a balance between ethnographic and experimental/correlational designs, and develop complementary mixed methods

## D'Alessandro et al. (2015) REVIEW

- Results section indicates search but then different article cited; number of citations do not match up with references: “A «web of knowledge» search with just two terms, «green space and health», yielded 2 hits for 1990-1999, 34 for 2000-2009, and 45 from 2010 to June 2013; in the same paper; authors performed a «review of reviews» on the topic until April 2013, involving 56 relevant reviews 2009, and 45 from 2010 to June 2013”
- Trees and other vegetation may reduce levels of some pollutants, including gases and particulate matter (PM), but they may also contribute to air pollution by releasing hydrocarbons, including isoprene and terpenes, with considerable variation by species

## Christian et al. (2015) REVIEW

- Reviewed 32 studies mostly conducted in US, Australia & Europe w/over two thirds (69%) examining behaviors (e.g., outdoor play & physical activity) through which children develop social–emotional competence, language & communication skills, rather than domains of early child development per se
- Evidence that presence of child relevant neighborhood destinations & services positively associated w/early child development domains of physical health & well-being & social competence; children living in higher density housing have limited access to private open space, thus accessibility & design of public open space is particularly important
- Characteristics of surrounding natural & built environments (i.e., places & spaces created or modified by people), can provide important resources & exposures relevant for early child health & development
- Reviews of correlates of children’s physical activity & outdoor play indicate that built environment features such as walk/bicycle paths, presence of cul-de-sac roads, access to parks, recreational facilities, other local destinations & public transport positively associated w/children’s physical activity, while high traffic exposure & crime negatively associated w/children’s physical activity
- Some evidence that **parent’s perceptions of neighborhood safety positively associated w/young children’s social–emotional development & general health**; with less space available for outdoor play, time spent indoors increased & this can reduce active play, exploration & physical activity & increase sedentary behaviors such as television viewing, w/possible negative consequences for early child health & development

Jennings et al. (2016) REVIEW

- Stressful qualities of city life can limit leisure opportunities & make city dwellers more susceptible to mental health challenges, greater exposure to urban green spaces can also alleviate challenges to psychological health

Younan et al. (2016) ORIGINAL RESEARCH

- Study of 1,287 individuals (of 640 families) including 276 MZ & 364 DZ twin pairs in Los Angeles, CA, US; used Normalized Difference Vegetation Index (NDVI); participants part of Risk Factors for Antisocial Behavior twin study based at University of Southern California; a prospective study of interplay of genetic, environmental, social & biological factors on development of antisocial behavior from childhood to early adulthood; aggressive behavior assessed using Child Behavior Checklist (CBCL/6-18); Children & adolescents (years 9-18)
- Beneficial impacts of greenspace have become increasingly recognized by public health advocates & has ability to improve overall well-being, decrease stress levels & reduce symptoms of depression, anxiety & attention-deficit/hyperactivity disorder; consider pathway explanation: 1) studies suggest maternal stress & depression increase externalizing behavioral problems in children & exposure to greenspace can improve mental health by reducing stress levels & lowering depression, 2) low self-esteem related to aggressive behavior in children & adolescents & intervention studies found greenspace improvements encourage participation in physical activity & increased physical activity improves self-esteem, 3) recent epi studies suggest ambient air pollution & ambient noise could increase aggressive behavior & greenspace may reduce air pollution & act as buffer for ambient noise, 4) many organisms important for immunoregulatory mechanisms & brain development are almost completely eliminated from urban environments but greenspace in urban areas preserves microbial biodiversity needed to drive immunoregulation & optimize brain health

Eisenman (2016) REVIEW

- Question remains if social cohesion outcomes associated with urban green space mediate an eventual relationship with human health
- Streetscape vegetation was at least as strongly related to self-reported health as green areas in the Netherlands, and the strongest links between greenness and reduced morbidity were found closest to home: within 1 km (0.6 mile) or roughly a 10-minute walk
- Air pollution pathway description; first of these explores three principle mechanisms: 1) deposition of fossil-fuel air pollution onto leaf surfaces and branches, 2) dispersion of fossil-fuel air pollution through the effect of urban flora upon air circulation & 3) emission or mitigation of volatile organic compounds (VOCs); other potential mechanisms include reduction of air pollution emissions from power plants via microclimatic cooling/wind-sheltering effects of trees near buildings & reduced formation of ground-level ozone (O<sub>3</sub>) through ambient and surface cooling

MacBride-Stewart et al. (2016) REVIEW

- In summary, **women were found to be more sensitive to the restorative values of natural environments**
- Notably, it is possible that definitions of green space have influenced findings and conclusions about health impacts
- Evident that different qualities are important to different groups so from a public health perspective, there may be particular challenges in matching the ‘right quality’ of space, for example, how much



green space is enough? What are the qualities of outdoor space that have the potential to influence gendered health outcomes? If there is a lack in quantity of space, how do we assure there is the right quality?

#### Nieuwenhuijsen et al. (2017) REVIEW

- Contact w/natural environment & health is mediated through number of possible mechanisms including air quality, physical activity, social contacts, stress & restoration; these mechanisms have number of possible modifiers, such as distance to green space, accessibility factors, perceived safety in green space, societal context, cultural context, gender, age & socioeconomic status
- Improvement in air quality, increase in social contacts, physical activity & reduction in stress all well known to be associated w/improved health
- May be relationship between green space & socioeconomic position making socioeconomic position potential confounder; however, impact of socioeconomic position on findings of studies of health effects of green spaces depends on local context & type of health outcome & can vary from minimal to moderate

#### Buckley and Brough (2017) REVIEW

- Reviewed articles focused in Australia but applicable to other locations with appropriate data; included park use patterns, mental health outcomes, and economic values
- Sources of data include: big data (e.g., national datasets) in 3 major categories; 1) park use patterns in 3 broad categories [(i) brief visits to natural environments in residential areas, variously known as neighborhood nature, metro nature, or urban greenspace; (ii) single-day visits to parks and other public lands allocated for conservation and/or recreation; and (iii) multi-day programs]; 2) principal types of mental health outcomes reported in previous studies include: improved attention, changed attitudes, improved cognition, reduced stress, anxiety, depression, reduced use of anti-depressants, improved recovery from stress, general improvements in mental health, improved sleep, improved general life satisfaction; 3) involves the estimation of economic values of mental health outcomes through multiple parallel additive pathways
- Framework provided in this study could be used to calculate financial gains from the mental health benefits of conservation, accruing specifically to health insurers, employers, and to taxpayer-funded health care systems

#### O Douglas et al. (2017) REVIEW

- Intervention for pregnant mothers include providing safe access & well-distributed accessible green space in areas characterized by social deprivation
- Life-course approach facilitates more nuanced understanding of those green space attributes that promote health & well-being than normally evident in much research in this field consequent on such research being generally cohort specific & focused on particular selection of variables

#### Abelt and McLafferty (2017) ORIGINAL RESEARCH

- Analyzed birth records for year 2000 provided by New York City Department of Health & Mental Hygiene for total of 103,484 singleton births to mothers who resided w/in New York City, NY limits; used Normalized Difference Vegetation Index (NDVI) & NYC Street Tree Census as measure of greenness; adjusted for individual factors - maternal & infant characteristics demonstrated to affect birth outcomes; infant's sex and season of birth; adjusted for neighborhood factors - socioeconomic status, tract-level deprivation index created based on eight variables: 1) percent of female-headed

households w/children under 18 & no husband present, 2) percent of households receiving public assistance income, 3) percent of households whose yearly income <\$35,000, 4) percent of individuals living below poverty line, 5) percent of individuals over 16 years old unemployed, 6) percent of employed individuals over 16 years old who worked in management or professional occupations, 7) percent of adults over 25 years old w/less than 12th grade education & 8) percent of occupied housing units w/1+ occupant per room

- Did not identify consistent significant relationship between adverse birth outcomes & NDVI, access to major green spaces when individual covariates taken into account
- Some research has demonstrated members of marginalized communities (in NYC) already have sufficient ‘access’ to green spaces when ‘access’ defined as living w/in reasonable walking distance of park but same communities also more likely to suffer from higher rates of neighborhood disamenities like violent crime, traffic hazards, and pollution which could serve to both degrade perceived safety &/or aesthetic value of local green spaces & discourage residents from leaving homes in order to visit those spaces

#### Dickinson and Hobbs (2017) REVIEW

- Reviewed 90 articles
- **Least tangible aspects of human-nature interface (e.g., sense of place, access to nature, aesthetics, spiritual beliefs) important contributors to well-being** but not well understood
- MEA used term “Cultural Ecosystem Services” (CES) to describe “nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences”
- Research has linked CES to improved physical health outcomes via changes to psychological well-being
- CES may be most important ecosystem services for city dwellers given that they represent some of most familiar & personal experiences of nature people encounter in urban context

#### E. Ekkel and Vries (2017) REVIEW

- Studies comparing different types of green space indicators suggest that cumulative opportunities indicators more consistently positively related to health than residential proximity ones
- W/regard to stress reduction & attention restoration seems to be no lower limit on size of green space, although larger areas w/more natural vegetation might offer more or deeper restoration than small areas w/little vegetation or only isolated natural elements
- W/regard to social cohesion, there is no obvious activity that would require green areas of minimum size
- Frequency of green space use declines w/increasing distance & proximity important determinant of use & has been reported that **distance of 100–300 m is threshold distance after which use declines rapidly**
- People are expected to travel further for desirable opportunities not available more nearby
- Using larger distances as cut-off point sometimes results in stronger associations between access to green space & health parameters than using shorter distances
- Crowding likely to be important so visiting green space simultaneously w/many other people may be less relaxing & high visitor densities may interfere w/well-being effects of visit - this has received little attention in research on nature & health
- Sturm & Cohen (2014) suggest **typical standard in US for walkable is 0.25 mile or 400 m distance at most** & similarly van den Bosch et al. (2015) propose guideline of having urban green space of at least 1 ha w/in 300 m direct line distance

- Large variety in accessibility metrics & health indicators make it hard to perform meta-analyses
- Cumulative opportunity indicators (both those using percent green space & those using average NDVI-score) tend to show better results than residential types of indicators

#### Bosch and Sang (2017) REVIEW

- Reviewed 13 total peer-reviewed articles written in English found in April 2016 ("only 3 of those were retrieved if including health in the search terms")
- "Old Friends hypothesis" is considered, where dysfunctional immune system suggested to be due to minimized contact w/biodiverse natural environments & consequentially non-sustained human microbiome which means that by increased exposure to natural environments & thereby biodiverse microbiota, protective effect against infectious & autoimmune disorders may be achieved
- Focus on greenness (meaning including all vegetation) or focus on green space is not clear distinction as most cover both type of studies in their review
- Strong evidence for positive effect of green spaces on improved affect
- Lack of evidence for effects on lung cancer mortality & birth weight & relative lack of evidence for mediators related to these outcomes (stress & physical activity)

#### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles; restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- With increasing knowledge concerning epigenetic & early life impact on health throughout life course, improved understanding of early exposures & possible preventive measures are of utmost importance; lifestyle behaviors established early in life (e.g., physical activity) tend to be maintained throughout life course & thereby improve health into adult life
- Health promotion (through e.g., attention restoration) may contribute substantively to life quality among elderly who often to higher extent than general population suffer from anxiety especially in cities
- Many studies specifically focused on children estimated green space or greenness using average NDVI as green space metric & relate value to certain distance or buffer from residence using 100, 250, or 500 m distances around residential areas
- For children focus of papers reviewed mainly on birth outcomes, mental health (particularly ADHD), obesity & overweight, asthma & allergy & for elderly health issues investigated were additionally on heat- and air pollution-related mortality, but also included mental health & perceived general health

#### Reid et al. (2017) ORIGINAL RESEARCH

- Study based in New York City, NY, USA w/1281 participants using 2010 High Resolution Land Cover dataset for New York City (NYC) to estimate association between near-residence trees, grass & total vegetation; 300 m & 1000 m buffers; Self-reported health measure was single validated item drawn from NYC Department of Health & Mental Hygiene Community Health Survey ("Would you say that in general your health is excellent, very good, good, fair or poor?"); 2nd model adjusted for age, sex, race/ethnicity, sampling frame, season, neighborhood tenure, individual-level SES (income, educational attainment) & area-level SES (percent living below two times FPL & percent unemployed at census tract); 3rd model adjusted for nitrogen dioxide; 4th model further adjusted for percent park percent non-park open spaces; near-residence trees, grass & total vegetation; calculated percent city-designated park area using NYC Department of Parks & Recreation Parks Properties

shapefile & percent non-park open space using NYC Open Space (not parks) shapefile w/in each radial buffer

- Six studies focusing on exposure to trees, without comparison to grass, reported associations w/increased physical activity, lower prevalence of obesity among preschoolers, lower prevalence of depression & stress among adults, lower rates of antidepressant prescriptions, better overall health & lower risk of small-for-gestational-age birth (Lovasi et al., 2011, Lovasi et al 2013, Beyer et al., 2014, Taylor et al., 2015, Ulmer et al., 2016, Donovan et al., 2011)
- Concern in neighborhoods research is ‘local trap’ in which many studies fail to recognize that people’s perceived & experienced neighborhoods often much larger than researchers may expect
- Cho et al., (2017) stated that trees release terpenes, many of which demonstrate anti-inflammatory, anti-tumorigenic & neuroprotective effects in toxicological studies
- Variation in findings by SES & type of vegetation could be due to differential perceptions of safety in greener areas, connectedness to nature, or quality of vegetation

#### Mennis et al. (2018) ORIGINAL RESEARCH

- 179 African American adolescents (13-14 years old) recruited between 2012-2014; Participants from Social-Spatial Adolescent Study, a longitudinal study focusing on the contextual mechanisms of adolescent substance use; ecological momentary assessment (EMA) data collection technique that involves repeated sampling of subject’s behaviors, moods & experiences in real time & in a subject’s natural environment often delivered via brief surveys over mobile phone; survey administered 3–6 times/day over 4-day period every other month over two year period during which subject enrolled in study; self-reported stress on continuous 1–9 scale; age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage; Richmond, VA, USA; used NDVI data derived from Enhanced Thematic Mapper Plus (ETM+) image dated September 12, 2013 carried aboard NASA’s Landsat 8 satellite & downloaded from public sources; 100 m buffer
- Adjusted for age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage
- Exposure to vegetation & natural areas can mitigate psychological stress by providing opportunities for physical activity & social interaction & by engendering cognitive & physiological responses associated w/psychological stress reduction & attention restoration following stressful experiences & may be particularly pronounced for those living in urban areas
- Adolescents in US report similar rates of stress as adults, which can act as catalyst for negative health outcomes over lifespan
- Mechanisms of stress for adolescents may differ from adults as adolescence marks critical developmental period & carries unique set of physical, sociological & psychological stressors
- As compared to adolescents generally, urban, African American adolescents may be particularly prone to additional contextual social & environmental stressors, as many African American urban neighborhoods exhibit concentrated economic disadvantage & disorder w/attendant high levels of crime, substance use & physical decay
- Stress reduction theory posits that because humans evolved in natural settings, they are genetically predisposed to respond favorably to greenspace thus exposure to certain natural landscapes invokes unconscious physiological response of lower stress
- Attention restoration theory suggests cognitive effort for certain tasks requires directed attention, which can result in attentional (or mental) fatigue & such fatigue may be acute in urban built-up areas, as urban landscape contain greater degrees of movement (e.g. cars, people) & visual & auditory stimuli as compared to natural environments, which can overload cognitive processing systems used for attentional focus

- Immersion in natural environments allows cognitive functioning for direct attention to rest & is thought to enhance attention restoration, attenuate mental fatigue & consequently relieve psychological stress
- May be that greenspace exposure has particularly attenuating effect on influence of neighborhood disadvantage on stress through partial alleviation of stressful environmental stimuli associated w/impoverished neighborhoods
- Did not find association between greenspace exposure & stress differs between boys & girls or between adolescents w/high & low emotional dysregulation

#### Fong et al. (2018) REVIEW

- Reviewed articles published January 2015 to October 2017
- When assessing relationship between greenness & health, there is uncertainty about etiologically most relevant time window of exposure
- Evidence for associations between greenness & asthma or allergy-related symptoms inconsistent & results suggest associations may strongly depend on study area
- Exposure to greenness thought to affect cardiovascular disease risk by contributing to levels of physical activity, stress, social engagement, noise & air pollution exposure
- Findings inconsistent across studies & cardiovascular outcomes suggest that strength of evidence for greenness & cardiovascular outcomes remains intermediate; greenness may influence mortality risk by buffering exposure to harmful pollutants, increasing physical activity, providing setting for social engagement, or through affecting mental health directly, all of which may affect downstream mortality rates
- Findings inconsistent & often contradictory for greenness & asthma & allergies & more information on vegetation species types needed to provide more clarity
- Findings less clear for other birth outcomes including preterm birth; evidence showing that SES modifies associations between greenness & birth outcomes, diabetes, obesity & mortality

#### C Twohig-Bennett and A Jones (2018) REVIEW

- Reviewed 143 total articles (103 observational, 40 interventional) investigating ~100 health outcomes until January 2017 & published in English; combined population size of > 290 million in 143 different studies analyzed
- 50% of studies were in Europe, the country w/highest frequency of included studies was Japan w/24; 11 different types of greenspace exposure were measured, most common of which was neighborhood greenspace (including residential greenspace, street greenery & tree canopy) measured by 56 studies
- Most frequently investigated health outcomes cardiovascular, including cardiovascular mortality, blood pressure, heart rate & incidence of angina & myocardial infarction
- Results were often not presented according to SES, meaning that formal subgroup analysis by SES level was not possible

#### Kondo et al. (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- Results mixed, or no association found, in studies of urban green space exposure & general health, weight status, depression & stress (via cortisol concentration)
- Number of studies too low to generalize about birth outcomes, blood pressure, heart rate variability, cancer, diabetes, or respiratory symptoms

- Most studies used vegetation index derived from satellite imagery e.g., normalized difference vegetation index (NDVI) to indicate amount of green space surrounding participant residences
- Whether or not someone engages in physical activity may be influenced not only by individual characteristics, but also by accessibility, features, condition & actual & perceived safety of their surrounding physical environment
- There have been numerous reviews of empirical studies on link between nature & human health, very few have focused on urban context & most have examined almost exclusively cross-sectional research
- Found only one study each of green space effects on birth outcomes, cancer & respiratory symptoms & found very few on stress
- Findings in all health outcome categories were mixed but consistent negative association found between urban green space exposure & mortality (all cause, cardiovascular & respiratory), measurements of heart rate (short-term) & violence, & positive association between urban green space exposure & attention & mood
- Number of studies too low to make generalizations about birth outcomes, blood pressure, heart rate variability, cancer, diabetes, or respiratory symptoms
- Experimental studies using between- or within-subjects design were not conducted w/random sampling of population & most conducted w/university students, sometimes of one sex
- **Very few studies focus on health inequalities, or impact of urban nature specifically on disadvantaged or vulnerable populations**
- This review of experimental, quasi-experimental & longitudinal studies found evidence of positive association between urban green space & attention, mood & physical activity & negative association w/mortality, short-term cardiovascular markers (heart rate) & violence

#### Barnes et al. (2019) REVIEW

- Reviewed 30 articles w/41 unique nature-exposure experience locations worldwide; definition of participant's experience: "description/detail of the nature" (or "nature of the nature" as they describe it)
- Participant Experience: ensure exposure experience descriptions are specific including: duration of nature-exposure experience for each participant; Information on whether participants were alone or with others; specific activities of participants (e.g., walking slowly and surveying nearby vegetation); map and provide a specific description of exposure route (if mobile) or exact location (if stationary)
- Exposure Location and Geography: identify and report nature-exposure exposure sites by most commonly known name (e.g., Golden Gate Park), or location in relation to another landmark (e.g., campus green space west of Coffey Hall, University of Minnesota), if no formal name exists; include location and map of where exposure took place and a description of the surrounding area which may include sights, sounds, and smells; include proximity, porosity/imperviousness, and relative density of adjacent structures
- Environmental Context and Natural Elements: photograph surroundings that participants would view or encounter during exposure; describe nearby built and natural features that participants may experience; Include not only amenities but also stressors, such as: sources of noise (e.g., nearby railroad lines, airports, highways, etc.); sources of strong odors (e.g., factories, construction, restaurants, etc.); other unique factors or stimuli that may influence participant experience
- Overarching Recommendations: use accessible tools including GIS software and Google Maps to summarize natural and neighborhood metrics of exposure sites; explore opportunities for conducting exposure studies in locations where existing evidence is lacking, particularly in the Global South;

encourage a broader range of seasonal experiences and exposure in nature as well as time of day and duration

#### CR Hall and MJ Knuth (2019b) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Many people no longer live near immediate or extended family members & subsequently become disengaged from traditional institutions & networks such as churches, labor unions & civic organizations that used to form basis for their social lives (Putnam 2000)
- Growing evidence that across North American cities, underprivileged populations have disproportionately less access to vegetation than affluent groups, raising concerns of environmental inequity resulting from these variations in urban vegetation for low-income citizens & visible minorities (persons of skin color that are underrepresented in a given region), w/disparities more pronounced on public land than on private land (Pham et al. 2012)

#### CR Hall and MJ Knuth (2019a) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Term “green spaces” has been used extensively to refer to areas of urban vegetation including public & private parks and gardens, residential landscapes & urban forests & other municipal landscapes; gap between natural setting, for which our physiological functions are adapted, & highly urbanized & artificial setting that we inhabit is contributing cause of “stress state” in modern people

#### C Hall and M Knuth (2019) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Term “stress recovery theory” coined by van den Berg and Custers (2011) & includes benefits derived when individuals immerse in nature, including decreased anxiety, lower heart rates, skin conductance recovery, lower concentrations of cortisol & positive changes in nerve activity
- Stress reduction & mental restoration occur when individuals live near green areas, have a view of vegetation, or spend time in natural settings
- City park area quantity & accessibility strong predictor of physical & community well-being

#### Saitta et al. (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016
- Legislative commitment ensuring urban parks are accessible may mitigate some health disparities in persons w/disabilities
- Urban parks important for community well-being & public health & offer approach to increase population & individual health & well-being & can provide venues for our inherent desire of ‘nature’ (i.e., biophilia hypothesis) & also provide opportunities for physical & leisure activities & social connection needs
- ‘Destination’ parks considered premier site that people in city would travel to in order to enjoy opportunities they provide & these urban parks are typically city managed & should be accessible at low or no financial cost
- Biopsychosocial benefits are contingent on parks having an environment which all generations & people of all abilities including persons w/disabilities should be able to access

- Mean ages of study participants of included studies classified as: children & adolescents, (0–18 yrs); young adults (18–35 yrs), middle age adults (36–55 yrs) & older adults (56+ yrs) to establish comparison groups
- Persons w/disabilities appear to experience same biopsychosocial health benefits of park-based physical activity as general population
- **Urban parks, when accessible & usable, foster community spirit & social capital via developing respect & inclusion for diversity of age & ability**
- Found that **limited accessibility deterred participation in park-based activities**
- **Influences on behavior include physical barriers to accessing built environments (e.g. lack of ramps, narrow pavement width for wheelchairs)** & emotional, psychological & societal barriers & safety concerns reported by persons w/disabilities
- WHO published Global Action Plan on Physical Activity which specifically states need to “create supportive spaces & places that promote & safeguard the rights of all people, of all ages & abilities, to have equitable access to safe places & spaces in their cities & communities in which they can engage in regular physical activity”
- Cohen et al., (2007) found that over 40% of park users are adults compared to children (33%) & older adults (5%)
- Lack of randomized controlled trials make it difficult to distinguish whether any of reported short-term improvements in physical & psychological health outcomes attributable to intervention (i.e. physical activity) or to park environment
- Used holistic definition of ‘disability’ by including people w/range of impairments including physical, sensory, intellectual & psychological impairments
- Ensuring that all parks are accessible & usable requires legislative commitment as **inaccessible parks contribute to health inequities for persons w/disabilities which contravenes human rights principles**

#### Kruize et al. (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Based on a **US** study by Reed & Price (2012), indications that **majority of park users are white, have (or are) children & engage in vigorous activity & that participants from high socioeconomic status areas found to use local park more frequently than those from low socioeconomic status areas** so actions to stimulate use of green spaces should focus on people who seldom if ever use them & when seeking to involve hard-to-reach groups, important to build trust & provide sense of structure & continuity
- Important that people aware of green space in their surroundings & that they appreciate value of it for their own activities & to raise awareness, clearly marked routes, good information & facilities on routes are needed
- Availability, size, connectedness of space, ease of accessibility, distance, quality, attractiveness & maintenance, are features of physical environment contributing to increased social interaction
- **Distance to destination, availability of suitable infrastructure (e.g., sidewalks, bicycle paths) & safety very important factors that motivate people to visit urban green space**
- Having children or having dog are other important motivators for using green space
- What makes green space attractive to people depends on factors like life stage, aspects of lifestyle & their individual values e.g., parents of young children want safe & pleasant spaces for their children to play, people w/out dependent children want spaces for socializing w/others & enjoyment of nature, while teenagers want places to “hang out” safely w/out being moved on by police or other adults
- **Important that people feel safe & that there is sense of social cohesion & perceived integration**



- Well-designed urban green space can buffer noise, or at least negative perception of noise emanating from non-natural sources like traffic & provide relief from city noise
- Many studies on green space & health use amount of green space as key indicator, but there are increasing indications that accessibility, type, quality & context of green space should be considered in assessment of relationships between green space & human health & well-being
- Green spaces have different meanings for people, both positive (related to identity, community, restoration, safety & freedom/unity) & negative (related to maintenance & crime & conflicts associated w/inequality & access)
- Further suggested pathway is that social support can buffer changes in neuroendocrine, cardiovascular & immune function & assuming that social support can be improved by increase in positive social interactions in green space, visiting green space may have beneficial effect through this pathway
- WHO (2012) found that **despite having greater access to public green space, those with higher educational attainment complained more often about lack of access to recreational or green areas than those w/lower levels of education**
- **Deprived communities, children, older people, people w/mental health problems & pregnant women greatest beneficiaries of urban green space** so provision & maintenance of appropriate green space in urban areas may make important contribution to reducing health inequalities & buffer some effects of stressors such as unemployment but literature shows that people from deprived communities often have less access to green space

#### Hunter et al. (2019) REVIEW

- Reviewed 38 articles from high income countries (e.g., US, United Kingdom, Australia)
- Findings provide particularly strong evidence for employing dual approaches that provide a change to the physical environment but also include programs to encourage and promote use of the UGS
- Unlike individual-level health promotion approaches, developing a supportive environment has the potential to achieve a greater reach by facilitating, population-wide improvements in health, and long-term effects
- Consideration of wider social and environmental benefits alongside health promotes the ‘multi-functionality’ of UGS interventions with impacts in multiple domains, demonstrating value more comprehensively

#### Lai et al. (2019) REVIEW

- Reviewed 275 articles
- Interesting finding: six studies (3%) described negative associations, including increases in mortality risk (Richardson et al. 2012), skin cancer (Astell-Burt et al. 2014b) & overall cancer risk (Zhang et al. 2016), asthma (Andrusaityte et al. 2016), and injury (Bortolini et al. 2016), as well as a reduction in physical-activity-based commuting (Maki-Opas et al. 2016)

#### Roberts et al. (2019) REVIEW

- Reviewed 33 articles from 10 different countries that investigated the effect of direct, short-term exposure to the natural environment on depressive mood; half of articles were on college students; confounders that were identified include: weather, food, alcohol and caffeine consumption, social interaction with other participants or researchers, environment participants were exposed to immediately before measurements started, and the length of time between the experimental and control environment exposures (if applicable); most studies used forests as their natural environment

- (n = 16), followed by urban or country parks (n = 11); most studies (n = 24) took mood measurements pre- and post-exposure to nature; all studies examine the effect of short term exposure to green space
- Observed effect sizes ranged from -2.30 to 0.84 after performing the meta regression; unweighted mean effect was -0.29 with standard deviation (SD) 0.6 which is interpreted as a small effect estimate; meta forest analysis was done to ensure reliability of results; model identifies the proportion of females in the sample, the type of natural and built environment, the type of effect size, the time between natural and built environment visits, the country of study origin, the gender mix of the sample, and whether or not a baseline measurement was taken to be the most important moderators of the effect size from the 20 that were entered; model predicts that for a sample with a lower proportion of women, the effect size is larger; effect size was also larger for agricultural, biodiverse and forest environments, compared to a park environment

#### Mygind et al. (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included one or more controlled studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight w/in-subjects designs)
- Participants predominantly 11-18 years (~80%) & ~10% of identified studies included participants <11 (3-7 years ≈3%, 7-11 years ≈ 7%) & children & adolescents w/behavioral and/or emotional disturbances (e.g. attention deficit hyperactivity disorder (ADHD) or depression), substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Focus on particular type of immersive nature-experience, namely Scandinavian tradition & practice of so-called friluftsliv, which includes concepts of, e.g. 'outdoor life', 'outdoor recreation & education' or 'adventure recreation & education', but w/emphasis on experience of closeness to nature during activity & defined health according to World Health Organization's holistic & positive definition of health & identified studies were divided into analytically distinct categories of mental, physical & social health
- Assessed risk of bias w/in & across individual studies & quality of evidence across studies at outcome level & across all outcomes, 60% (n = 56) were improved pre to post immersive nature-experience compared to control conditions and groups, 18% (n = 17) of all outcomes improved pre to post interventions, but no more than control conditions & groups & remaining 22% (n = 20) indicated mixed or insignificant findings; conditional support for benefits for children & adolescents on self-esteem, self-efficacy, resilience & academic & cognitive performance from immersion in nature; for both outcomes self-concept & mood findings from longer-term interventions indicated beneficial outcomes, whereas no differences could be observed following short-term interventions; at present, evidence premature as basis for conclusions pertaining to optimal or minimum time spent in nature

#### Wolf et al. (2020) REVIEW

- Reviewed 201 total articles sorted into 3-part framework (reducing harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; restoring capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; building capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants

- Of 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults & 13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults; Controlling for socio-economic factors common among cross-sectional studies
- Applying prospect/refuge theory, more positive affects (e.g., attentiveness) & reduced negative affects (e.g., anger, aggression, fear) were found in high prospect-low refuge environments (Gatersleben & Andrews 2013), suggesting that spatial arrangements & configurations of trees, in addition to general nature content, can influence health response (Kaplan 20110)
- Given small number of studies, relationship between trees & birth outcomes in urban areas remains unclear
- Studies typically investigated short-term benefits such as improved blood pressure, stress reduction & cognitive restoration

#### Grilli and Sacchelli (2020) REVIEW

- Reviewed 36 articles
- Review results indicated that most scientific attention concentrated on stress levels associated w/urban–forest dichotomy & all contributions confirm good forest performance in relation to stress reduction; also consider risks due to allergenic reactions, pests, insects, falling branches & trees as negative impacts

#### Browning and Locke (2020) ORIGINAL RESEARCH

- Study in Maryland, US using Chesapeake Conservancy land dataset [(1) tree cover, (2) herbaceous/low vegetation & shrub cover (hereafter, “grass cover”) & (3) total vegetation cover] & 4) & 5) derived from red & infrared wavelengths that were transformed into normalized difference vegetative index values; point data for schools retrieved from Maryland GIS Data Catalog; attendance areas retrieved from National Center for Education Statistics; school parcel polygons accessed via Maryland Property View; math & reading test scores from 2016 retrieved from Maryland School Report Cards; Racial, ethnic & gender composition of students & student-to-teacher ratios obtained from National Center for Education Statistics; total of 668 public schools, 8-9 year olds (3rd grade) student test scores from 2015-2016; greenspace measures calculated in two zones: 1) around school + 25 m buffer & 2) in school attendance boundaries + 25 m buffer; Greenspace measures calculated in two zones: 1) around school + 25 m buffer & 2) in school attendance boundaries + 25 m buffer
- Controlled for random effects attributable to broader social, geographic & environmental context of United States county where each school located; Random effects attributable to broader social, geographic & environmental context of United States county where each school located
- **Greenspace may also support self-discipline, engagement, physical activity, autonomy & “loose parts” for creative play while providing calm, quiet, safe & cooperative social environments**
- This study is 6th observational, school-level study that does not provide strong support for beneficial relationship between standardized test scores & school greenspace
- Reviews of association between greenspace & academic performance & physical health show outcomes vary widely by way greenspace measured
- **Tree & forest cover generally shows stronger protective effects than total vegetation cover or herbaceous/grass cover**, findings observed in studies of academic performance, self-reported well-being & birth outcomes; students find trees more restorative than grassy lawns so may receive more mental & physical health restoration from forested areas

**Specific Population: Prenatal / Pregnancy**





## Population Focus / Mention: Prenatal / Pregnancy

**Summary:** Findings from nine articles suggested that there is a positive relationship between greenspace and various birth outcomes, such as birth weight (Chawla 2015; Kabisch et al., 2017; Douglas et al., 2017; Abelt and McLafferty 2017), small for gestational age, and pre-term birth (Twohig-Bennett and Jones 2018). More recent articles examining these outcomes suggest consistent and strong evidence that higher levels of greenness are associated with higher birth weights, higher levels of physical activity during pregnancy, and lower mortality rates (Fong et al., 2018) among pregnant women. Greenspaces may influence these birth outcomes by altering pregnant mothers' levels of physical activity during pregnancy, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise and air pollution exposure, and by moderating ambient temperatures (Hall and Knuth 2019). In some cases, stronger associations between greenness and birth outcomes were observed among those whose parents had lower levels of education and were of lower socio-economic status (Abelt and McLafferty 2017; Hall and Knuth 2019). Note: “(CROSSOVER WITH xxx)” indicates that the same information can be found in the appropriate section (i.e., mental, physical, social / other, or other findings).

### Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using key words “child\*,” “youth,” “young people,” or “adolescents” in combination with “health” or “well-being” and “natural environment,” “green space,” or “parks”; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); ethnographic work on children in nature in the 1970s and later years was gathered through the author's participation in the development of this field
- Confounders adjusted for in articles included air pollution, noise, temperature where confounders noted in the section on physical health
- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety (CROSSOVER WITH PHYSICAL)
- Protective effects of nature at birth including higher birthweight with higher levels of greenness (CROSSOVER WITH PHYSICAL)

### E. Ekkel and Vries (2017) REVIEW

- Gražulevičienė et al., (2014) found having **access to green, recreational space w/in 300 m associated w/lower probability of high-normal blood pressure during pregnancy** (CROSSOVER WITH PHYSICAL)

### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles w/restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Results from studies on relationship between urban green & neonatal outcomes (e.g., birth weight) showed positive trend but were somewhat inconsistent (CROSSOVER WITH PHYSICAL)

### O Douglas et al. (2017) REVIEW

- Effect of greenness on pregnancy & birth outcomes studied extensively & positive associations between greenness & birth weight of babies observed across majority of studies (CROSSOVER WITH PHYSICAL)
- Studies found linked increased exposure of pregnant mothers to green space w/lower odds of child being small for gestational age or preterm/premature & lower infant mortality risk (CROSSOVER WITH PHYSICAL)
- Research showed that exposure by pregnant women to green space & nature may have affected birth outcomes by altering their levels of physical activity, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise & air pollution exposure & moderating ambient temperatures (CROSSOVER WITH PHYSICAL)
- Majority of analyses have adjusted for race, maternal age, season of conception, area-level socio-economic factors & child's sex w/consistent results identified (CROSSOVER WITH PHYSICAL)

#### Abelt and McLafferty (2017) ORIGINAL RESEARCH

- Analyzed birth records for year 2000 provided by New York City Department of Health & Mental Hygiene for total of 103,484 singleton births to mothers who resided w/in New York City, NY limits; used Normalized Difference Vegetation Index (NDVI) & NYC Street Tree Census as measure of greenness; adjusted for individual factors - maternal & infant characteristics demonstrated to affect birth outcomes; infant's sex and season of birth; adjusted for neighborhood factors - socioeconomic status, tract-level deprivation index created based on eight variables: 1) percent of female-headed households w/children under 18 & no husband present, 2) percent of households receiving public assistance income, 3) percent of households whose yearly income <\$35,000, 4) percent of individuals living below poverty line, 5) percent of individuals over 16 years old unemployed, 6) percent of employed individuals over 16 years old who worked in management or professional occupations, 7) percent of adults over 25 years old w/less than 12th grade education & 8) percent of occupied housing units w/1+ occupant per room
- Significant association between street trees surrounding home & reduced odds of preterm birth; access to major green spaces not significantly related to odds of preterm birth in these models nor were any of other neighborhood-level covariates (CROSSOVER WITH PHYSICAL)
- Access to major green spaces & neighborhood covariates not significantly associated w/small for gestational age in models (CROSSOVER WITH PHYSICAL)
- Most notable finding evidence of inverse relationship between local street trees & increased odds of preterm birth (CROSSOVER WITH PHYSICAL)
- Recent investigations into association between green space & birth outcomes have demonstrated relatively consistent results (n=13 studies) which examined variety of outcomes, but all included at least one outcome related to birthweight &/or gestational age & in all but two cases & NDVI used as primary measure of greenness (CROSSOVER WITH PHYSICAL)
- Results of these studies provide support for protective relationship between green space & birthweight as significant positive association between greenness & birthweight-related variables observed for at least subset of population in all studies (CROSSOVER WITH PHYSICAL)
- Studies found stronger associations between greenness & decreased risk of adverse birth outcomes among women of lower socioeconomic status (n=5) (CROSSOVER WITH PHYSICAL)

#### C Twohig-Bennett and A Jones (2018) REVIEW

- Reviewed 143 total articles (103 observational, 40 interventional) investigating ~100 health outcomes until January 2017 & published in English; combined population size of > 290 million in 143 different studies analyzed

- Meta-analysis results showed **increased greenspace exposure associated w/decreased risk of preterm birth** 0.87 (95% CI 0.80, 0.94), **small size for gestational age** 0.81 (95% CI 0.76, 0.86) (CROSSOVER WITH PHYSICAL)

Kondo et al. (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- Cusack et al., (2017) measured maternal residential green space in metropolitan areas of Texas for 3,026,603 births at 1st, 2nd & 3rd trimesters & for total pregnancy, controlling for known individual & neighborhood confounding factors (e.g., demographic background & smoking status) & did not find consistent effects on birth weight, odds of preterm birth or small for gestational age but did find some protective effects of increased residential greenness for mothers with low education, mothers that lived in low-income neighborhoods, or for Hispanic mothers (CROSSOVER WITH PHYSICAL)

Fong et al. (2018) REVIEW

- Reviewed articles published January 2015 to October 2017
- Maternal exposure to greenness thought to affect birth outcomes via increasing physical activity, improving mental health & buffering detrimental effects of air pollution, noise & extreme heat exposures (CROSSOVER WITH PHYSICAL)
- Cusack et al., (2017) did large birth cohort study in Texas examining 3 million+ births & found that **among full-term births, birth weight higher when NDVI levels during pregnancies higher & those children born to mothers living in greenest areas (NDVI >0.52) had on average 1.9 grams (95% CI 0.1, 3.7) higher birth weight compared w/those born to mothers who lived in least green areas (NDVI <0.37)** & evidence that SES-related variables such as ethnicity, education & neighborhood characteristics modified relationship between greenness & birth outcomes w/strongest associations observed in lower SES groups (CROSSOVER WITH PHYSICAL)
- Higher odds of preterm birth, defined as being born at <37 weeks of gestation associated w/lower exposures to greenness & green spaces around maternal residence in some studies (CROSSOVER WITH PHYSICAL)
- Bijmens et al., (2015) employed novel biomarker & assessed telomere length in umbilical cord blood cells collected 24 hours after delivery; short telomere lengths have been used as measure of accelerated aging & short telomere lengths in cord blood cells been linked to early insulin resistance & impaired fetal growth & brain development in children & **found 22% increase in proportion of green space 5000 m around maternal residence associated w/on average 3.62 (95% CI: 0.20, 7.15) % longer telomere** (CROSSOVER WITH PHYSICAL)
- Consistent & strong evidence that higher levels of greenness associated w/higher birth weights, higher levels of physical activity & lower mortality rates (CROSSOVER WITH PHYSICAL)

CR Hall and MJ Knuth (2019a) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Davvand et al., (2012a) found **greater exposure to plants affects birth outcomes by altering increasing maternal levels of physical activity, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise & air pollution exposure & moderating ambient temperatures** (CROSSOVER WITH PHYSICAL)

- Higher greenness exposure linked to lower odds of child being small for gestational age or preterm (Hystad et al. 2014), larger head circumferences (Dadvand et al. 2012a) & lower infant mortality risk (CROSSOVER WITH PHYSICAL)
- Stronger associations between greenness & birth outcomes observed among those whose parents had lower levels of education & lower socio-economic status (Agay-Shay et al. 2014, Dadvand et al. 2012a, Markevych et al. 2014) (CROSSOVER WITH PHYSICAL)



**Specific Population: Child (0 to 18 years)**





### Population Focus / Mention: Child (0-18 years)

**Summary:** Children benefit mentally, physically, and socially from access and exposure to urban greenspaces and findings from twenty-six peer-reviewed articles are presented below. Regarding physical health, children are most studied subgroup examining nature and physical activity (Hartig et al., 2014), and urban greenspaces can provide children with a more natural landscape in which to play, which helps to increase motor fitness, balance and coordination compared with children who have access to only traditional outdoor playgrounds (Christian et al., 2015). Mental health benefits from interactions with urban greenspaces include alleviation of attention deficit hyperactivity disorder (ADHD) symptoms, improvements in concentration capacity (Kabisch et al., 2017; Douglas et al., 2017), and it has been suggested that “doses of nature” might serve as a safe, inexpensive, widely accessible way to manage ADHD symptoms (Douglas et al., 2017). Natural areas provide for more imaginative, constructive, sensory, and socially cooperative play (Chawla 2015), which is important for strengthening of social inclusion and friendships across cultures (Kruize et al., 2019). Note: “(CROSSOVER WITH xxx)” indicates that the same information can be found in the appropriate section (i.e., mental, physical, social / other, or other findings).

McCormack et al. (2010) REVIEW

- Reviewed 21 articles; Focus group interviews most common method of collecting data (68%), then individual interviews (67%), then situ observation (24%), w/six studies including multiple data collection methods (29%); several studies include ethnic groups: African Americans, Native Americans, and Latino and Hispanics; socioeconomic status levels of participants varied across studies; seven studies included data collection from children or adolescents
- Studies involving children/adolescents indicated **access to variety of facilities in parks that supported active & passive recreational activities including those for structured (e.g., sports) & unstructured (e.g., play) activities important** (CROSSOVER WITH SOCIAL / OTHER)
- Facilities that supported children’s play (e.g., playgrounds, trees for climbing) also important
- **Importance of accessibility for encouraging park use among children regardless of gender, ethnicity & socioeconomic status** (CROSSOVER WITH SOCIAL / OTHER)

Zhou and Rana (2012) REVIEW

- **Green space improves self-discipline, lowers rate of truancy & allows for even better scholar achievement in children** (CROSSOVER WITH SOCIAL / OTHER)

Keniger et al. (2013) REVIEW

- Reviewed 57 peer-reviewed scientific literature prior to June 2011
- Evidence that childhood interactions w/nature may influence attitudes towards nature in later life & while not necessarily a benefit per se, there is much interest from sustainability perspective in how attitudes & behaviors that are positive toward nature develop (CROSSOVER WITH SOCIAL / OTHER)
- Taylor et al., (2001) found that in study of children diagnosed w/Attention Deficit Disorder (ADD) in US tested whether indirect interactions w/nature, such as exposure to nature during play, were related to attentional function, parents & carers of 96 children w/ADD completed questionnaire about child’s attentional functioning after participating in leisure activities & **mean post-activity attentional functioning ratings were significantly higher for green outdoor activities as opposed to those in other settings & severity of ADD symptoms was significantly lower after playing in natural areas outdoors** (CROSSOVER WITH MENTAL)

#### Berto (2014) REVIEW

- Strife & Downey (2009) found that children playing in highly natural school playgrounds showed fewer attention & concentration problems & improved cognitive & physical functioning than children playing in less natural school playgrounds (CROSSOVER WITH MENTAL)

#### Hartig et al. (2014) REVIEW

- Reviewed 59 articles (only "review" articles)
- Children are most studied subgroup examining nature & physical activity but results of studies have been mixed (CROSSOVER WITH PHYSICAL)
- Ding et al., (2011) found that ~40% of the studies in which environmental characteristics were objectively measured showed park access or vegetation to be positively associated with children's physical activity levels (CROSSOVER WITH PHYSICAL)
- In the other 60% of studies, no association was observed
- Some research does suggest that restorative childhood contact with nature can cumulatively provide benefits with far-reaching developmental significance & that contact with nature may for example improve attentional function in children with ADD (CROSSOVER WITH MENTAL)

#### Christian et al. (2015) REVIEW

- Reviewed 32 articles mostly conducted in US, Australia & Europe w/over two thirds (69%) examining behaviors (e.g., outdoor play & physical activity) through which children develop social-emotional competence, language & communication skills, rather than domains of early child development per se
- In a number of related quasi-experimental studies of 5–7 year olds (n=75), Fjørtoft showed that **children provided w/natural landscape (forest) in which to play, experienced significant increase in motor fitness, balance & coordination** compared w/children who played only in traditional outdoor playgrounds (Fjørtoft, 2004, Fjørtoft and Sageie, 2000, Fjørtoft, 2001) (CROSSOVER WITH PHYSICAL)
- Overall outdoor play & physical activity in early years positively associated w/neighborhood greenness (Lovasi et al., 2011, Grigsby-Toussaint et al., 2011), access to nature (Fjørtoft and Sageie, 2000), green public open space (Taylor et al., 1998, Aarts et al., 2010), parks (Roemmich et al., 2006) & playgrounds (Quigg et al., 2011, Sallis et al., 1993) (CROSSOVER WITH PHYSICAL)
- Some evidence to suggest that green spaces may be important for young children's cognitive (Wells, 2000, Kuo and Taylor, 2004) & motor (Fjørtoft, 2004, Fjørtoft and Sageie, 2000, Fjørtoft, 2001) development (CROSSOVER WITH MENTAL)
- High density housing has potential to positively impact early child development through increased opportunities for social interaction between neighbors & potentially greater density of proximate amenity & services but may constrain opportunities for play because lack of private & public indoor & outdoor space limits children's ability to play (Gifford, 2007, Evans, 2006)
- Strong empirical evidence that neighborhoods which are safe from traffic & which have green spaces (i.e., nature, public open space, parks, playgrounds) are associated w/behaviors (i.e., outdoor play & physical activity) that facilitate early child health & development (CROSSOVER WITH PHYSICAL)
- This review highlights that neighborhood physical environment may be more important for some domains of early child health & development (e.g., physical health & well-being & social competence) than others (e.g., language & communication skills) & that children's play in natural environments more diverse, imaginative & creative than children's play in other settings (Strife and Downey, 2009) (CROSSOVER WITH MENTAL)

Rakhshandehroo et al. (2015) REVIEW

- Olsson et al., (2012) found that **access to green environment has positive impact on children's physical movement skills & outdoor activities** & increases knowledge & awareness of environmental issues; most children would prefer to play outdoors rather than indoors (Byrne & Sipe, 2010) & they enjoy landscaped spaces of all sizes & dimensions & prefer more secluded landscaped areas (Sarkissian, 2013) as locations w/shady trees & fresh green grass are more conducive environments for children than those devoid of such elements of nature (Singh et al., 2010) (CROSSOVER WITH PHYSICAL)
- **Green space provides children w/range of sensory experiences & helps them refine motor skills, achieve social development & practice social skills** (Gilliland, Holmes, Irwin & Tucker, 2006; Gearin & Kahle, 2006) (CROSSOVER WITH SOCIAL / OTHER)

Chawla (2015) REVIEW

- Reviewed articles from January 2010 to June 2015; a search was made of the databases Web of Science, PubMed, and PsycInfo, using the key words “child\*,” “youth,” “young people,” or “adolescents” in combination with “health” or “well-being” and “natural environment,” “green space,” or “parks”; Research Resources database of the Children and Nature Network was also scanned (<http://www.childrenandnature.org/learn/research-resources>); Ethnographic work on children in nature in the 1970s and later years was gathered through the author's participation in the development of this field
- Confounders adjusted for in articles included air pollution, noise, temperature where confounders noted in the section on physical health
- Green space and increased physical activity confounded by age, sex, SES, race, income, perceived neighborhood safety
- Contact with nature can reduce symptoms of ADD and attention deficit and hyperactivity disorder (ADHD) in children (CROSSOVER WITH MENTAL)
- **Proximity to parks and other green spaces linked to healthier weight or lower body mass index in children** (CROSSOVER WITH PHYSICAL)
- Access to green space & street trees increased physical activity (CROSSOVER WITH PHYSICAL)
- Because psychological well-being is a subjective experience as well as an expert diagnosis, levels of greenery have been related to children's self-assessments, parent's perceptions of their children's condition, and professional diagnoses & all of these measures indicate that access to nature is a protective factor (CROSSOVER WITH MENTAL)
- **Natural areas provide for more imaginative, constructive, sensory, and socially cooperative play** than asphalt, flat expanses of lawn, or built play equipment (CROSSOVER WITH MENTAL)

Jennings et al. (2016) REVIEW

- Nature has specific impacts on attention restoration, concentration, stress reduction & social interactions contributing to youth development
- Larson et al., (2013) found many parents recognized diverse physical, mental & social health benefits associated with their children's outdoor recreation experiences in Georgia state parks, particularly when these experiences involved bonding interactions with family and friends (CROSSOVER WITH SOCIAL / OTHER)
- Studies linking benefits from green spaces w/aspects of educational achievement & cognitive functioning (CROSSOVER WITH MENTAL)

- Wu et al., (2014) examined relationship between academic performance & surrounding greenness among elementary schools in Massachusetts, after adjusting for confounding variables (e.g., income levels, English not being students' first language, attendance, gender & levels of urbanization), determined that higher levels of greenness associated w/higher student performance in English & math (CROSSOVER WITH SOCIAL / OTHER)
- Other research observed similar positive links between nearby green space & student performance among high school students in Michigan & school-aged children in New England (CROSSOVER WITH SOCIAL / OTHER)

#### Younan et al. (2016) ORIGINAL RESEARCH

- Study of 1,287 individuals (of 640 families) including 276 MZ & 364 DZ twin pairs in Los Angeles, CA, US; used Normalized Difference Vegetation Index (NDVI); participants part of Risk Factors for Antisocial Behavior twin study based at University of Southern California; a prospective study of interplay of genetic, environmental, social & biological factors on development of antisocial behavior from childhood to early adulthood; aggressive behavior assessed using Child Behavior Checklist (CBCL/6-18); Children & adolescents (years 9-18)
- Crude analyses showed aggressive behaviors decreased w/increasing exposure to short-term (1-, 3- & 6-months) & 3-year average NDVI in 1000 m before CBCL assessment; adjustment for sociodemographic factors, neighborhood quality & 6-month average temperature resulted in increase in strength of short-term effect estimates for NDVI averaged in 1000 m buffer; adjusted analyses suggested **consistent pattern of decreased aggression associated w/increasing greenspace w/in 1000 m buffer, w/both short-term & long-term beneficial effects equivalent to 1.9 to 2.2 years & 2.1 to 2.5 years of age-related behavioral maturation**, respectively; effect estimates not sensitive to further adjustment for proximity to freeways or roads, traffic density in 150- or 300 m area, or maternal smoking during pregnancy; living w/in close proximity to park, golf course, or field, in comparison to residing in location surrounded by other housing, shopping centers, or freeways, was equivalent to having increased NDVI associated with 0.36 to 0.41 reduction in aggressive behavior scores (CROSSOVER WITH MENTAL)

#### McCormick (2017) REVIEW

- Reviewed 12 articles
- Overall well-being and psychological distress were measured using the Strengths and Difficulties Questionnaire (SDQ) in three studies finding that high quality and quantity green space was associated with better child well-being (Feng & Astell-Burt, 2017), less total difficulties, emotional symptoms, and peer relationship problems (Amoly et al., 2014), and a > 20 min walk to green space was associated with worse mental and overall health (Aggio et al., 2015) (CROSSOVER WITH MENTAL)
- **Children performed better on attention tasks and spatial working memory after a walk in nature** compared to a walk in an urban landscape (Schutte, Turquati, & Beattie, 2017) (CROSSOVER WITH MENTAL)
- Green outdoor settings were found to reduce symptoms of inattention and hyperactivity in children diagnosed with ADHD (Kuo & Faber Taylor, 2004), and inverse relationship was found between residential greenness and ADHD/DSM-IV total and inattention scores (Amoly et al., 2014) (CROSSOVER WITH MENTAL)

#### L Nesbitt et al. (2017) REVIEW

- Reviewed 38 articles focused on North America that examined the services of mixed vegetation (i.e., multiple or unspecified types of vegetation), 31 studies that examined the services of trees, and 43 studies that examined the services of green spaces
- Urban greenery can reduce childhood obesity & improve ADHD (CROSSOVER WITH PHYSICAL & MENTAL)

#### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles & restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Previous research showed that children's cognitive, emotional & motor development may be associated w/exposure to nature (Amoly et al., 2014, Dadvand et al., 2015) & these developmental effects of nature exposure may explain why many studies have suggested that nature exposure reduces symptoms in children suffering from attention deficit hyperactivity disorder (ADHD) (CROSSOVER WITH MENTAL)
- Two studies investigating effect of green space availability on overweight in preschool-aged children (Kabisch et al., 2016, Schüle et al., 2016) found that individual child & parental factors (parental overweight, low- and middle-level parental education or social status) main predictors of overweight, while urban green space availability not independently associated w/overweight (CROSSOVER WITH PHYSICAL)
- Markevych et al., (2014) found association between lower systolic blood pressure levels in 10-year-old children living in urban residences & higher greenness using NDVI (CROSSOVER WITH PHYSICAL)
- Younan et al., (2016) showed exposure to green space w/in 1000 m surrounding residences associated w/reduced aggressive behaviors in children 9–18 years of age (CROSSOVER WITH MENTAL)
- **Interactions w/green spaces have positive effect in alleviating symptoms of ADHD & improving concentration capacity** (Taylor et al., 2001, Faber Taylor and Kuo, 2009) (CROSSOVER WITH MENTAL)

#### O Douglas et al. (2017) REVIEW

- Important to focus on adolescent group since prone to physical inactivity & studies show that people more likely to be physically active as adults if they were physically active in late teens (CROSSOVER WITH PHYSICAL)
- **Strong relationship between frequent childhood visits to green space & being prepared to visit such places alone as an adult** (CROSSOVER WITH SOCIAL / OTHER)
- Important from health standpoint since childhood inactivity has been identified as key risk factor in many chronic diseases of later life & early socially-stimulating environments have been shown to strongly inform later emotional well-being & cognitive capacity (CROSSOVER WITH PHYSICAL)
- Almanza et al., (2012) found higher odds of physical activity identified among 8–14 year olds when in greener areas compared to less green areas (CROSSOVER WITH PHYSICAL)
- Prospective study including children & youth aged 3–16 years by Bell, Wilson, and Liu (2008) found that higher greenness significantly associated w/lower Body Mass Index (BMI) values after 24 months (CROSSOVER WITH PHYSICAL)
- Examination of impacts of environments on attention in **children w/Attention Deficit Hyperactivity Disorder (ADHD)**, Taylor and Kuo (2009) found that subjects **concentrated better after walk in park** than after downtown walk or walk in neighborhood, concluding that **“doses of nature” might serve as safe, inexpensive, widely accessible way to manage ADHD symptoms** (CROSSOVER WITH MENTAL)

- Prospective study of 7–10 years old primary school children, Dadvand et al., (2015) observed improved cognitive development in children exposed to green surroundings, controlling for factors such as socio-demographics & pollution (CROSSOVER WITH MENTAL)
- Kyttä et al., (2012) identified 10–15 year olds more likely to report they had very good health when there was significant green space around their home, after controlling for neighborhood socio-economic status (CROSSOVER WITH SOCIAL / OTHER)
- 32 studies explored environmental characteristics contributing to physical activity among youth (age 8–21), characteristic most frequently reported to promote physical activity was access to green space, measured either as distance from one's home to parks & green areas, or as % green coverage or number of recreational facilities in neighborhood, higher amount & closer distance = more park used w/positive effect on physical activity (CROSSOVER WITH PHYSICAL)

#### Kondo et al. (2018) REVIEW

- Reviewed 68 total articles focused on studies taking experimental, quasi-experimental, or longitudinal approaches published from January 1976 to December 2017 in urban areas
- Richardson et al., (2017) conducted longitudinal cohort study of children between 2005 & 2010 w/participants approximately 1-year-old at recruitment & using Strength & Difficulties Questionnaire & controlling for many individual, family & neighborhood factors found that increasing exposure to green space (measured as % green space & parks w/in ward of residence) associated w/improved social outcomes (CROSSOVER WITH SOCIAL / OTHER)
- Wolch et al., (2011) examined association between proximity to parks w/childhood obesity using data from eight annual survey waves from longitudinal cohort study of 3,173 children in California & while controlling for multiple potential confounding factors, **BMI growth at age 18 inversely associated w/park access (park acres w/in 500 m of residence) more so for boys than for girls** (CROSSOVER WITH PHYSICAL)
- Lachowycz et al., (2012) found that **up to 30% of moderate-to-vigorous physical activity (MVPA) among 10–11-year olds was done in parks**, tracking location of MVPA using combination of wearable GPS & accelerometer (CROSSOVER WITH PHYSICAL)
- Almanza et al., (2012) found that **MPVA nearly five times greater among children that spent more than 20 minutes of time in green space**, than among children w/no green space exposure (CROSSOVER WITH PHYSICAL)
- Younan et al., (2016) examined association between violent behavior (aggression) & urban green space exposure (average NDVI surrounding residence) using longitudinal cohort study w/four waves finding that increased exposure to green space associated w/reduced aggressive behaviors (CROSSOVER WITH MENTAL)

#### Fong et al. (2018) REVIEW

- Reviewed articles published January 2015 to October 2017
- MacNaughton et al., (2017) study used ecological approach in Massachusetts w/greenness around schools as exposure & chronic absenteeism as outcome, defined as percent of students missing 10% or more of total school days in year & found an IQR (0.15) increase in NDVI associated w/2.6% decrease in chronic school absenteeism (CROSSOVER WITH SOCIAL / OTHER)

#### Mennis et al. (2018) ORIGINAL RESEARCH

- 179 African American adolescents (13-14 years old) recruited between 2012-2014; Participants from Social-Spatial Adolescent Study, a longitudinal study focusing on the contextual mechanisms of

adolescent substance use; ecological momentary assessment (EMA) data collection technique that involves repeated sampling of subject's behaviors, moods & experiences in real time & in a subject's natural environment often delivered via brief surveys over mobile phone; survey administered 3–6 times/day over 4-day period every other month over two year period during which subject enrolled in study; self-reported stress on continuous 1–9 scale; age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage; Richmond, VA, USA; used NDVI data derived from Enhanced Thematic Mapper Plus (ETM+) image dated September 12, 2013 carried aboard NASA's Landsat 8 satellite & downloaded from public sources; 100 m buffer

- Adjusted for age (at EMA), sex, race, emotional dysregulation, setting, season & neighborhood disadvantage
- Results indicate that urban greenspace is associated w/lower stress when subjects are away from home possibly due to properties of stress reduction & attention restoration associated w/exposure to natural areas & primacy of other family dynamics mechanisms of stress w/in home (CROSSOVER WITH MENTAL)
- Greenspace-stress association away from home did not differ by sex, emotional dysregulation, neighborhood disadvantage, or season (season suggesting that observed greenspace-stress relationship associated w/being in natural environment rather than strictly exposure to abundant green vegetation) (CROSSOVER WITH MENTAL)
- Taylor & Kuo (2009) suggest that greenspace exposure may have particular health effects for youth w/certain mental health conditions & experimental research suggests that **urban youth w/attention deficit/hyperactivity disorder (ADHD) maintain better concentration after exposure to park settings** (CROSSOVER WITH MENTAL)
- Kuo & Taylor (2004) found that **outdoor activities in natural areas can mitigate symptoms of ADHD among youth**; only setting is significant as moderator (OR = 1.98,  $p < 0.05$ ) where greenspace associated w/lower stress at EMA responses that occur when subject is away from home (CROSSOVER WITH MENTAL)
- Speculate that association of greenspace w/lower stress found here due to properties of stress reduction, attention restoration & amelioration of mental fatigue associated w/exposure to vegetation & natural areas among urban residents (CROSSOVER WITH MENTAL)

#### Mygind et al. (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included one or more controlled studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight w/in-subjects designs)
- Participants predominantly 11-18 years ( $\approx 80\%$ ) &  $\sim 10\%$  of identified studies included participants  $< 11$  (3–7 years  $\approx 3\%$ , 7–11 years  $\approx 7\%$ ) & children & adolescents w/behavioral and/or emotional disturbances (e.g. attention deficit hyperactivity disorder (ADHD) or depression), substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Childhood mental, physical & social well-being & lifestyle have been associated w/late-life behaviors, function & well-being so health promotion & prevention targeting children has never been more pertinent (CROSSOVER WITH SOCIAL / OTHER)



- Eight of 11 unique studies from six publications found that nature-based programs improved participants' self-esteem more than comparison conditions (American Institutes for Research, 2005; Hayhurst et al., 2015; Hunter et al., 2013; Kafka et al., 2012; Mann, 2007; Romi and Kohan, 2004) but due to serious risk of bias across studies, quality of evidence considered low (CROSSOVER WITH MENTAL)
- Five of seven unique studies in four publications concluded that **immersive nature-experiences lead to increases in self-efficacy** (Connelly, 2012; Fuller et al., 2017; Hayhurst et al., 2015; Hunter et al., 2010) (CROSSOVER WITH MENTAL)
- White et al., (2012) found that a 3-month outdoor education program increased self-concept & Larson et al., 2007 found 5-day adventure camp only increased youngest children's (7-11 years of age) self-concept but due to serious risk of bias & indirectness stemming from lack of no treatment control group for three of the studies reviewed (Gehris, 2007; Jelalian et al., 2011, 2006), quality of evidence considered low (CROSSOVER WITH MENTAL)
- American Institutes for Research (2005) found that problem solving improved upon 5-day outdoor science school program & reported that at-risk & underachieving participants' academic performances improved following 5-day outdoor science school program (CROSSOVER WITH SOCIAL / OTHER)
- Hohashi & Kobayashi (2013) found fatigue, tension & excitement improved amongst adolescent girls in natural versus urban environments but due to high risk of bias across studies & imprecision introduced by small sample sizes, quality of evidence rated low (CROSSOVER WITH MENTAL)
- Norton & Watt (2014) found under-resourced urban adolescents 13-18 years old reported improvements in levels & prevalence of depression over course of 7-8 day expedition (CROSSOVER WITH MENTAL)
- Norton et al., (2007) found adolescents w/diagnosed depression reported lower levels of family conflict post 21-day wilderness therapy program (CROSSOVER WITH MENTAL)
- Mygind et al., (2009) found primary school pupils reported improved levels of social relations, for example, levels of teasing & quarrelling, influence on play & helping behaviors, when participating in education outside classroom in natural environments compared to classroom-based teaching (CROSSOVER WITH SOCIAL / OTHER)
- Mutz & Müller (2016) reported improvements in perceived stress amongst primary school pupils pre to post 9-day hike & university students after 8-day wilderness expedition (CROSSOVER WITH MENTAL)
- When focusing on studies in which control group had been included, outcomes such as self-esteem, self-efficacy, resilience, academic performance, cognitive performance & social skills & behaviors predominantly enhanced by immersive nature-experiences (CROSSOVER WITH MENTAL)

#### CR Hall and MJ Knuth (2019b) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- Younan et al., (2016) found when assessing level of aggressive behavior in young adolescence, both **short-term (1 to 6 month) & long-term (1- to 3 year) exposures to greenspace w/in 1000 m (3280 feet), surrounding residences associated w/reduced aggressive behaviors** so benefit of increasing vegetation above levels commonly seen in urban environments was equivalent to 2 to 2.5 years of behavioral maturation (CROSSOVER WITH MENTAL)
- As children's direct connection to neighborhood biodiversity progressively declines, it can have serious implications for public health & biodiversity conservation at community level (CROSSOVER WITH SOCIAL / OTHER)

- Rich multi-sensory experience of being outdoors encourages children to be more observant of & curious about their surroundings, leading to desire to explore, investigate & make sense of their observations (CROSSOVER WITH SOCIAL / OTHER)
- Symbolic play, in which children allow 1 thing to represent another or in which they take on roles & allow themselves to represent another persona, considered an important element in development of abstract thinking (Kemple et al. 2016) (CROSSOVER WITH SOCIAL / OTHER)

#### CR Hall and MJ Knuth (2019a) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- **Periods of moderate-to-vigorous physical activity significantly more likely to occur in green spaces for boys**, but relationship was positive but not statistically significant for girls (Wheeler et al. 2010) (CROSSOVER WITH PHYSICAL)
- **Children & adolescents w/better access to parks less likely to have higher BMI levels** (Wolch et al. 2011) & level of children's physical activity seems influenced by access to parks & vegetation (Ding et al. 2011) (CROSSOVER WITH PHYSICAL)

#### C Hall and M Knuth (2019) REVIEW

- Reviewed 1,348 total citations compiled & 2/3 conducted since 2011
- **Children w/ADHD concentrated better after walk in park** than after downtown neighborhood walk (Taylor and Kuo 2009) (CROSSOVER WITH MENTAL)
- Wilson (2015) showed that **children who play in greenspace for 30 minutes had increased sustained mental ability & found greenspace restorative** (CROSSOVER WITH MENTAL)
- **Nature exposure can influence cognitive development in children through improved working memory & reduction in inattentiveness** (Dadvand et al. 2015) (CROSSOVER WITH MENTAL)

#### Saitta et al. (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016
- Physical health gains from physical activity in children & adolescents appear to be incidental & were gained primarily via play in park (Jeanes & Magee 2012; Ripat & Becker 2012) (CROSSOVER WITH PHYSICAL)
- Some evidence to suggest that accessible parks could foster integration & social inclusion (Jeanes & Magee 2012; Ripat & Becker 2012) (CROSSOVER WITH SOCIAL / OTHER)
- Play can be even more effective for development of social skills in children w/autism, intellectual, physical & sensory disabilities & for children w/low social skills (CROSSOVER WITH SOCIAL / OTHER)

#### Kruize et al. (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Van den Berg & Van den Berg (2011) found that **contact w/nature may improve attentional function in children w/attention deficit disorder & enhance self-discipline in children w/out diagnosis** (CROSSOVER WITH MENTAL)
- Flouri et al., (2014) using data from 6,384 children participating in Millennium Cohort Study, revealed that access to garden & use of parks & playgrounds related to fewer conduct problems (problems related w/antisocial behavior) & fewer peer & hyperactivity problems & poor children

aged 3–5 years old & living in urban neighborhoods w/more greenery had fewer emotional problems than their counterparts in less green neighborhoods (CROSSOVER WITH MENTAL)

- **Public urban green space plays important role in children’s & young people’s social networks including friendships across cultures & promoting social inclusion** (CROSSOVER WITH SOCIAL / OTHER)
- Being nature oriented & having positive childhood experiences of nature motivate green space use which emphasizes importance of bringing children into contact w/nature (CROSSOVER WITH SOCIAL / OTHER)

#### Wolf et al. (2020) REVIEW

- Reviewed 201 total articles sorted into 3-part framework (reducing harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; restoring capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; building capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants
- Of 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults & 13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults; controlling for socio-economic factors common among cross-sectional studies
- Seo et al., (2015) found that **among children w/asthma or atopic dermatitis, short visit to forest resulted in significant improvements in various measures of disease severity & immunological effects** (CROSSOVER WITH PHYSICAL)

#### Browning and Locke (2020) ORIGINAL RESEARCH

- Study in Maryland, US using Chesapeake Conservancy land dataset [(1) tree cover, (2) herbaceous/low vegetation & shrub cover (hereafter, “grass cover”) & (3) total vegetation cover] & 4) & 5) derived from red & infrared wavelengths that were transformed into normalized difference vegetative index values; point data for schools retrieved from Maryland GIS Data Catalog; attendance areas retrieved from National Center for Education Statistics; school parcel polygons accessed via Maryland Property View; math & reading test scores from 2016 retrieved from Maryland School Report Cards; Racial, ethnic & gender composition of students & student-to-teacher ratios obtained from National Center for Education Statistics; total of 668 public schools, 8-9 year olds (3rd grade) student test scores from 2015-2016; Greenspace measures calculated in 2 zones: 1) around school + 25 m buffer & 2) in school attendance boundaries + 25 m buffer; greenspace measures calculated in 2 zones: 1) around school + 25 m buffer & 2) in school attendance boundaries + 25 m buffer
- Controlled for random effects attributable to broader social, geographic & environmental context of United States county where each school located; random effects attributable to broader social, geographic & environmental context of United States county where each school located
- Bivariate correlations suggested all measures of greenspace positively & significantly related to math & reading test scores ( $p < 0.05$ ); 250 m<sup>2</sup> NDVI significantly & positively associated w/reading & math scores in school zones & neighborhood zones (CROSSOVER WITH SOCIAL / OTHER)
- Tree cover in school zones & grass cover in neighborhood zones positively associated w/reading scores (CROSSOVER WITH SOCIAL / OTHER)
- Only two interaction terms statistically significant in models w/neighborhood zone greenspace measures: 30 m<sup>2</sup> NDVI in math models & 30 m<sup>2</sup> NDVI in reading models (CROSSOVER WITH SOCIAL / OTHER)

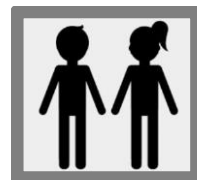
- Coarse-resolution greenness measures predicted academic performance in initial models but these associations disappeared when urbanicity was controlled for (CROSSOVER WITH SOCIAL / OTHER)

Hartley et al. (2020) REVIEW

- Reviewed 7 articles; 6/7 studies used NDVI
- Out of the seven reviewed papers, six reported no statistically significant direct relationships between greenness and child asthma while one (Donovan et al., 2018) found one **standard deviation increase in NDVI was associated with a 6% lower risk of asthma** (95% CI: 1.9%-9.9%) (CROSSOVER WITH PHYSICAL)
- 3 papers reported **greenness was protective for child asthma via mediation of other negatively related health factors, such as difficult family relationships** (Chen et al., 2017), **high traffic volume** (Feng & Astell-Burt, 2017), **and tobacco smoke exposure** (Eldeirawi et al., 2019) (CROSSOVER WITH PHYSICAL)
- **Greenness** has no direct effect on child asthma but **may be protective via modification of individual and community-level risk factors** (CROSSOVER WITH PHYSICAL)

**Specific Population: Teen**





### Population Focus / Mention: Teen

**Summary:** Fewer studies focus specifically on teenage populations, but four relevant articles suggest that access and safety of urban greenspaces are important factors in determining whether teenagers utilize such spaces and engage in physical or social activities in that environment (Lee and Maheswaran 2011).

Wilderness therapy or outdoor education programs were explored for teenagers with behavioral or emotional disturbances, which resulted in improved resilience and problem-solving competences, social awareness, self-management & relationship management over as little time as two days (Mygind et al., 2019). Note: “(CROSSOVER WITH xxx)” indicates that the same information can be found in the appropriate section (i.e., mental, physical, social / other, or other findings).

#### Gearin and Kahle (2006) ORIGINAL RESEARCH

- 16 high school seniors (n = 5 girls, n = 11 boys; n = 15 Hispanic, n = 1 Asian-American) & adults in Los Angeles, CA, USA; focus group & survey (CROSSOVER WITH SOCIAL / OTHER)
- Attitudes towards urban open &/or green space revolved around multiple uses for park space, safety issues & concerns about trash & maintenance (CROSSOVER WITH SOCIAL / OTHER)
- Ten separate responses related to issues of personal safety offered during discussion; some perceived streets as potentially unsafe areas in which to recreate or socialize & particular streets unsafe because of history of violent activities & traffic (CROSSOVER WITH SOCIAL / OTHER)
- Preference for places that offer range of activities centered on socializing; teens identified places typically overlooked in terms of greening opportunities, such as neighborhood underpass (tunnel) & local alleyways (CROSSOVER WITH SOCIAL / OTHER)
- Possible that being outside in environment less bound by rules than school library resulted in greater sense of speaking comfort & encouraged more responses (CROSSOVER WITH SOCIAL / OTHER)
- Urban teenagers participating in research—living in a park-poor, high density area—aware of & had experienced personal & collective benefits from parks (CROSSOVER WITH SOCIAL / OTHER)

#### McCormack et al. (2010) REVIEW

- Reviewed 21 articles; Focus group interviews most common method of collecting data (68%), then individual interviews (67%), then situ observation (24%), w/six studies including multiple data collection methods (29%); several studies include ethnic groups: African Americans, Native Americans, and Latino and Hispanics; socioeconomic status levels of participants varied across studies; seven studies included data collection from children or adolescents
- **Constructed and natural trails important among adolescent girls** (CROSSOVER WITH SOCIAL / OTHER)

#### Lee and Maheswaran (2011) REVIEW

- Reviewed 35 articles
- **Teenagers living in disadvantaged neighborhoods lacked access to parks they considered safe & were therefore less likely to participate in physical activities than teens in more affluent neighborhoods** (CROSSOVER WITH PHYSICAL)

#### Mygind et al. (2019) REVIEW

- Reviewed 84 English language articles published between January 2004 & May 2017 in Danish, English, Norwegian or Swedish language (of which 32 publications included one or more controlled

studies subjected to quality assessment & w/in these 32 publications, 28 studies used controlled, between-subjects designs & eight w/in-subjects designs)

- Participants predominantly 11-18 years (≈80%) & ~10% of identified studies included participants <11 (3–7 years ≈3%, 7–11 years ≈ 7%) & children & adolescents w/behavioral and/or emotional disturbances (e.g. attention deficit hyperactivity disorder (ADHD) or depression), substance abuse issues, juvenile delinquency, socially disadvantaged backgrounds, overweight & typically developing children & adolescents; main type of activity was expedition or base camp adventure experiences inscribed in educational (e.g. teambuilding, anti-bullying initiatives) or health context (e.g. psychological &/or behavioral treatment)
- Two individual studies from Hayhurst et al., (2015) including different populations reported improvements in resilience amongst high school students following 10-day voyage but quality of evidence considered low; Gillespie & Allen-Craig (2009) amongst 14-16 year-old males described as at-risk, resilience was increased over course of 5-week residential wilderness therapy (CROSSOVER WITH SOCIAL / OTHER)
- Sproule et al., (2013) reported increase in 13 year-old pupils' problem solving competences pre- to post-12-day outdoor education program & Gillespie and Allen-Craig (2009) found 14-16 year-old males' problem solving increased over course of 5-week residential wilderness therapy (CROSSOVER WITH SOCIAL / OTHER)
- Harper et al., (2007) found academic performance of 13–18 year-old males but not females w/emotional & behavioral challenges increased from pre- to post-21 days of wilderness therapy (CROSSOVER WITH SOCIAL / OTHER)
- Norton & Watt (2014) found under-resourced urban adolescents aged 13 to 18 reported improvements in family support over course of 7- to 8-day expedition (CROSSOVER WITH SOCIAL / OTHER)
- Ee & Ong (2014) found secondary pupils aged on average 14.1 years old reported that their social awareness, self-management & relationship management improved over course of 2-day camp (CROSSOVER WITH SOCIAL / OTHER)

**Specific Population: Elderly Adults**







## Population Focus / Mention: Elderly Adults

**Summary:** Accessible urban greenspace for older adults is important for general health and well-being. Findings from seven articles suggest that access and exposure to urban greenspace can influence the mental, physical, and social health of older adults. Access can provide activities that keep older adults physically active, provide social contacts and opportunities for social interaction, improve general quality of life (Kruize et al., 2019), and minimize loneliness and boredom (Saitta et al., 2019). The psychological and social benefits of parks, as opposed to physical benefits, were found to be of primary importance to older adults in general population (Saitta et al., 2019). Note: “(CROSSOVER WITH xxx)” indicates that the same information can be found in the appropriate section (i.e., mental, physical, social / other, or other findings).

### Lee and Maheswaran (2011) REVIEW

- Reviewed 35 articles
- Takano et al., (2002) found that availability of green space reported to be independently associated w/increased survival in elderly populations (CROSSOVER WITH PHYSICAL)

### Zhou and Rana (2012) REVIEW

- Kweon et al., (1998) note **older people in inner city w/greater accessibility to green space have more social ties than others** (CROSSOVER WITH SOCIAL / OTHER)
- Sugiyama et al., (2009) found that green space particularly important to maintain & enhance quality of life of older people (CROSSOVER WITH SOCIAL / OTHER)
- Sugiyama & Thompson (2007) found that **walkable green space elongates age of senior citizens regardless of their sex, marital status & socioeconomic status & sleeping ability** which troubles many old people can be largely improved (CROSSOVER WITH SOCIAL / OTHER)

### Kabisch et al. (2017) REVIEW

- Reviewed 27 articles; restricted search to articles published in English from 2010 onward to highlight recent advances in subject
- Proximity to green space (near homes of residents) may improve longevity of senior citizens (Takano et al., 2002) (CROSSOVER WITH PHYSICAL)
- Kawachi & Berkman (2001) indicated potential to be outside in green space to increase older people's health (CROSSOVER WITH SOCIAL / OTHER)
- Sugiyama & Thompson (2007) have demonstrated that neighborhood environments likely to contribute to health of elderly by providing opportunity spaces for being active (CROSSOVER WITH SOCIAL / OTHER)
- Arnberger et al., (2017) found that elderly prefer to visit nearby green spaces that provide shade, water (e.g., ponds) & cooler environment than their homes (CROSSOVER WITH SOCIAL / OTHER)
- Ode Sang et al., (2016) assessed self-rated health perceptions & mental health finding that higher perceived naturalness generated more activities, higher aesthetic values & self-reported well-being in residents living close to urban green spaces & that **elderly residents participated in greater number of nature-related activities than younger residents & reported improved mental well-being associated w/urban green** (CROSSOVER WITH MENTAL)
- Dzhambov and Dimitrova (2014) found negative correlation between actual time & frequency of interacting w/park & health anxiety among elderly people (CROSSOVER WITH MENTAL)

### O Douglas et al. (2017) REVIEW

- Villeneuve et al., (2012) found increased exposure to greenness proximate to place of residence linked w/reduced overall non-accidental mortality among elderly inhabitants (CROSSOVER WITH PHYSICAL)
- Kweon, Sullivan, and Wiley (1998) investigated relationship between older adults' exposure to nearby public green spaces & level of social integration & attachment to local community; Study determined correlations between use of public green space & strength of neighborhood social ties & sense of community; for older adult residents of inner-city deaths have been recorded in areas characterized by low greenness & increased exposure to greenness proximate to neighborhoods (CROSSOVER WITH SOCIAL / OTHER)

Saitta et al. (2019) REVIEW

- Reviewed 10 total papers (n = 6 quantitative & n = 4 qualitative w/n = 446 total participants) of all study designs peer-reviewed & published in English w/full-text available from inception until November 30, 2016
- Physical activity in park reported as intentional as parks provided place & purpose for rehabilitation as well as perception that they would mitigate deteriorating health in social environment (Chow 2013; Finlay et al., 2015) (CROSSOVER WITH PHYSICAL)
- **Accessible parks could minimize loneliness & boredom** (Chow 2013; Finlay et al., 2015); Gardner (2014) found that in park use by older adults, **psychological & social benefits of parks, not physical, were of primary importance to older adults in general population** & that any engagement in physical activity in park was predominantly incidental (CROSSOVER WITH SOCIAL / OTHER)
- Results on psychological & social benefits important finding given that over 45% of older adults report being lonely (CROSSOVER WITH SOCIAL / OTHER)

Kruize et al. (2019) REVIEW

- Reviewed international scientific literature published in English between 2006 & 2016
- Older people derive considerable pleasure & enjoyment from viewing & being in nature which has positive impact on their well-being & quality of life & those living in inner-city neighborhoods benefit from presence & use of green spaces which promotes social ties & sense of community (CROSSOVER WITH SOCIAL / OTHER)
- Older people are important target group because **access to green space provides activities that keep them physically active, provide social contacts, help to structure their day-to-day lives & improve quality of life in general & for people w/mental health problems, it may reduce symptoms like depression, anxiety & stress & increase self-esteem** (CROSSOVER WITH SOCIAL / OTHER)

Wolf et al. (2020) REVIEW

- Reviewed 201 total articles sorted into 3-part framework (reducing harm, representing 41% of studies, including topics such as air pollution, ultraviolet radiation, heat exposure & pollen; restoring capacities, at 31%, includes attention restoration, mental health, stress reduction & clinical outcomes; building capacities, at 28%, includes topics such as birth outcomes, active living & weight status) published prior to March 1, 2018; sample sizes ranged from eight to 625 participants
- Of 201 studies, 39% based in North America, 67 studies undertaken in United States, 9 in Canada & 1 in Mexico; full range of human life span represented, as 13% of studies focused on young adults &

13% on children & adults were primary age group studied (71% of studies) w/3% focusing on older adults; controlling for socio-economic factors common among cross-sectional studies

- Mao et al., (2012) found that among participants w/cardiovascular disease (CVD), **exposure to forest settings found to improve symptoms of hypertension** more than urban settings, including: lower blood pressure & homocysteine (a CVD-related pathological factor) in elderly adults (CROSSOVER WITH PHYSICAL)

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# APPENDIX

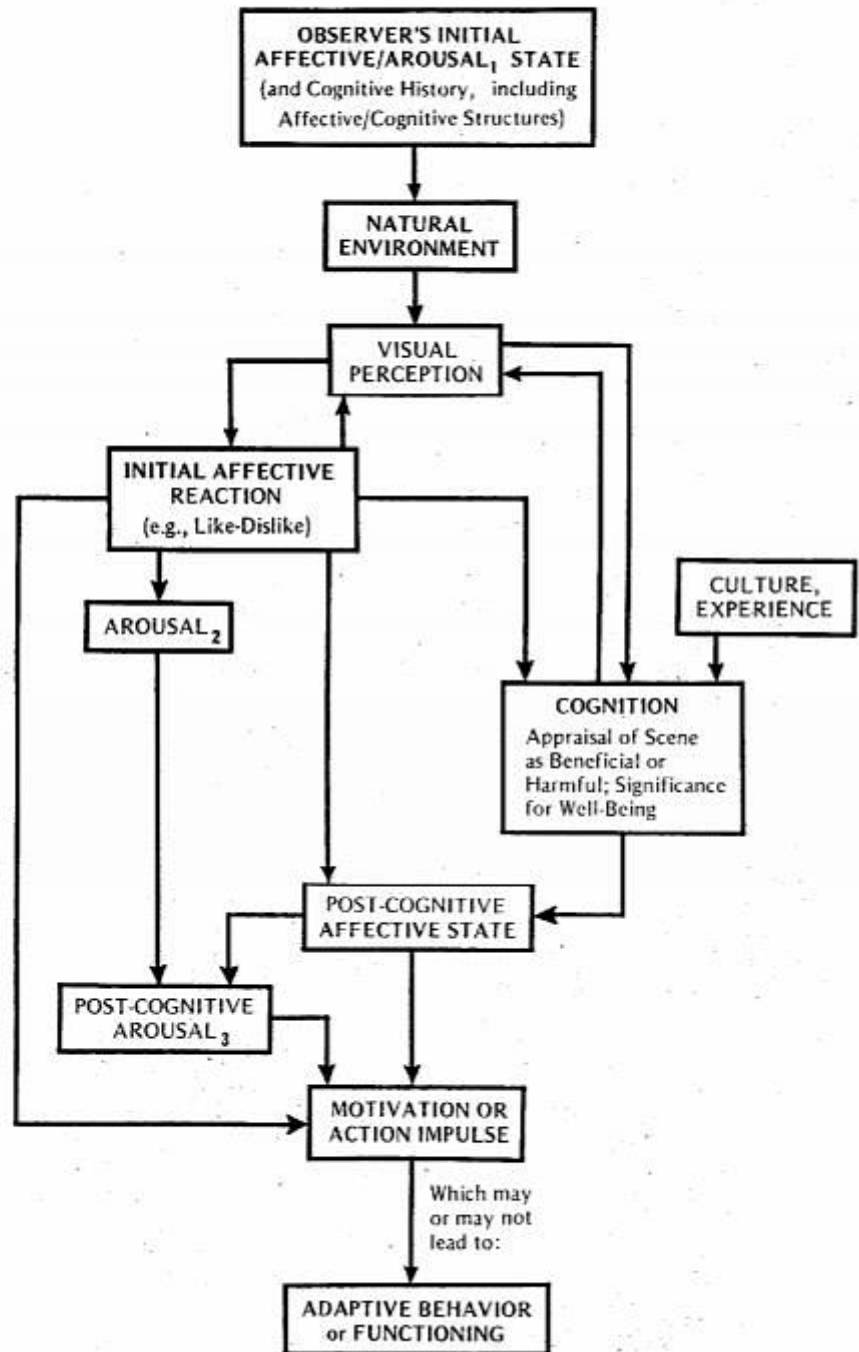
Table 1. Figures from reviewed articles summarizing various health benefits of urban greenspace.

Reference	Note	Image
<p>Saitta, M., Devan, H., Boland, P., &amp; Perry, M. A. (2019). Park-based physical activity interventions for persons with disabilities: A mixed-methods systematic review. <i>Disability and Health Journal</i>, 12(1), 11-23.</p>	<p>Fig.2</p>	
<p>van den Bosch, M., &amp; Sang, A. O. (2017). Urban natural environments as nature-based solutions for improved public health—A systematic review of reviews. <i>Environmental research</i>, 158, 373-384.</p>	<p>Fig.2</p>	

Knecht, C. (2004). Urban nature and well-being: Some empirical support and design implications. *Berkeley Planning Journal*, 17(1).

Fig.1

**Figure 1:** Ulrich's model of the interaction between a scene, affect, and physiological arousal.



(Source: Ulrich 1983, p. 91)

**Table 1:** Transcendence typology and key landscape elements. Summarized from Williams and Harvey 2001

Experience	Feelings	Landscape elements	Fascination	Novelty	Compatibility
<b>Highly Transcendent</b>					
Diminutive	Feelings of insignificance or humility. No sense of relaxation or belonging.	Distinctive, powerful elements: tall trees, waterfalls, extremes of heat and cold, dense settings where movement is blocked.	High	Very High	Low
Deep Flow	A sense of ease or effortless attention. Sense of oneness, no separation between self and forest.	Relatively open terrain, familiar and considered with affection and belonging.	High	Medium	High
<b>Weakly Transcendent</b>					
Aesthetic Experiences	Heightened awareness. Similar to Diminutive Experiences, except less sense of insignificance.	Beautiful or interesting single elements (e.g., nice view, butterfly flitting through the grass).	Slightly Low	High	Low
Restorative-Familiar	Refreshment, peace and quiet, sense of renewed energy.	Familiar locations (e.g., returning to the family's country home).	Slightly Low	Very Low	Moderate
Restorative-Compatibility	Refreshment, peace and quiet, sense of renewed energy. Less intense form of Deep Flow.	Non-distinctive elements that are highly compatible with doing desired activities.	Low	High	Very High
<b>Non Transcendent</b>					
Non Transcendent		Dense, fairly familiar, not potent or complex.	Very Low	Low	Very Low

Knecht, C. (2004). Urban nature and well-being: Some empirical support and design implications. *Berkeley Planning Journal*, 17(1).

Tabl.1

Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature?. *International journal of environmental research and public health*, 10(3), 913-935.

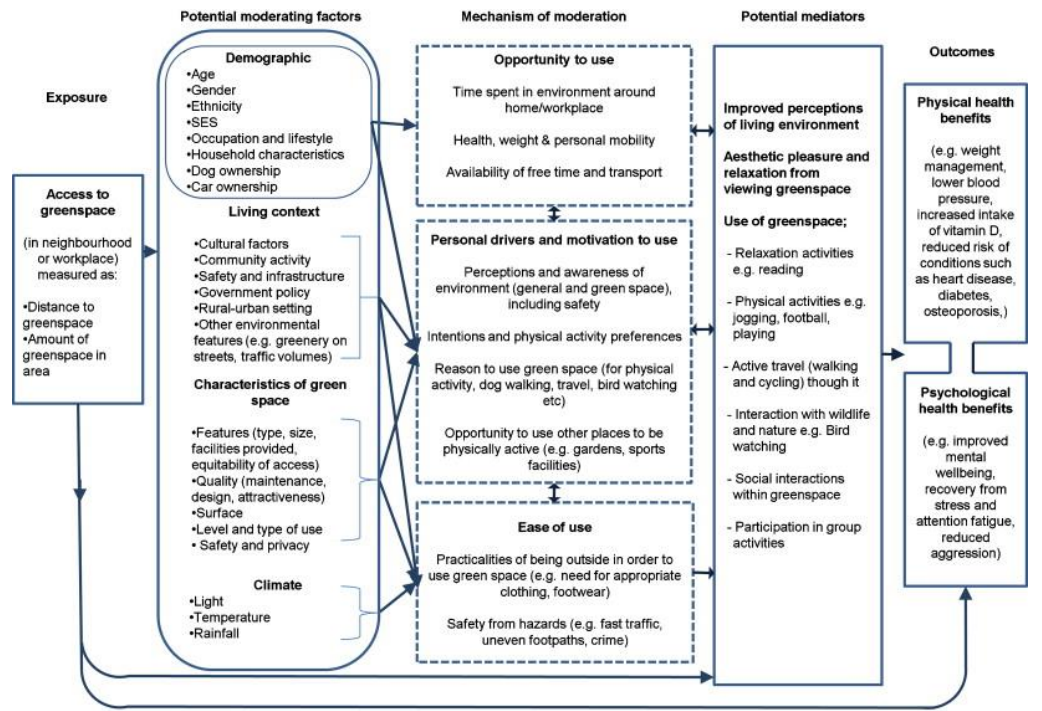
Tabl.3

Table 3. Typology of the benefits of interacting with nature.		
Benefit	Description	Examples
Psychological well-being	Positive effect on mental processes	Increased self-esteem [32, 60, 61]
		Improved mood [58, 32]
		Reduced anger/frustration [62]
		Psychological well-being [13, 63, 64]
		Reduced anxiety [65]
Cognitive	Positive effect on cognitive ability or function	Improved behaviour [15]
		Attentional restoration [12, 14, 46, 66, 67]
		Reduced mental fatigue [63]
		Improved academic performance [68]
		Education/learning opportunities [49, 55]
		Improved ability to perform tasks [15]
Physiological	Positive effect on physical function and/or physical health	Improved cognitive function in children [69]
		Improved productivity [35, 68]
		Stress reduction [37, 70, 71]
		Reduced blood pressure [45, 32]
		Reduced cortisol levels [70]
		Reduced headaches [37]
		Reduced mortality rates from circulatory disease [24]
		Faster healing [9]
		Addiction recovery [43]
		Perceived health/well-being [59]
Social	Positive social effect at an individual, community or national scale	Reduced cardiovascular, respiratory disease and long-term illness [11]
		Reduced occurrence of illness [15, 35]
		Facilitated social interaction [72, 73]
		Enables social empowerment [62, 74]
		Reduced crime rates [25]
		Reduced violence [63]
Spiritual	Positive effect on individual religious pursuits or spiritual well being	Enables interracial interaction [16]
		Social cohesion [72]
		Social support [72]
Tangible	Material goods that an individual can accrue for wealth or possession	Increased inspiration [42]
		Increased spiritual well-being [41, 47]
		Food supply [38]
		Money [50, 75]

Lachowycz, K., & Jones, A. P. (2013). Towards a better understanding of the relationship between greenspace and health: Development of a theoretical framework. *Landscape and urban planning*, 118, 62-69.

Fig.1

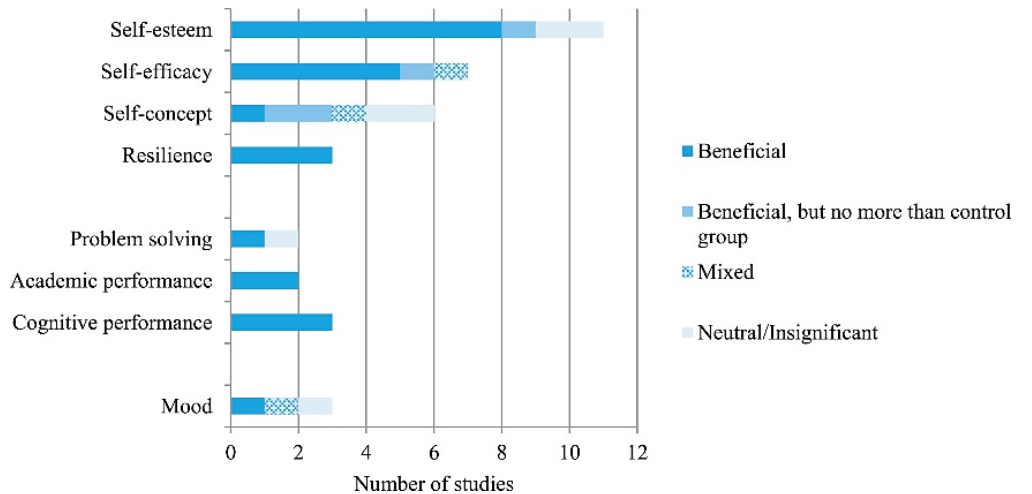
Socio-ecological framework for the relationship between greenspace access and health.

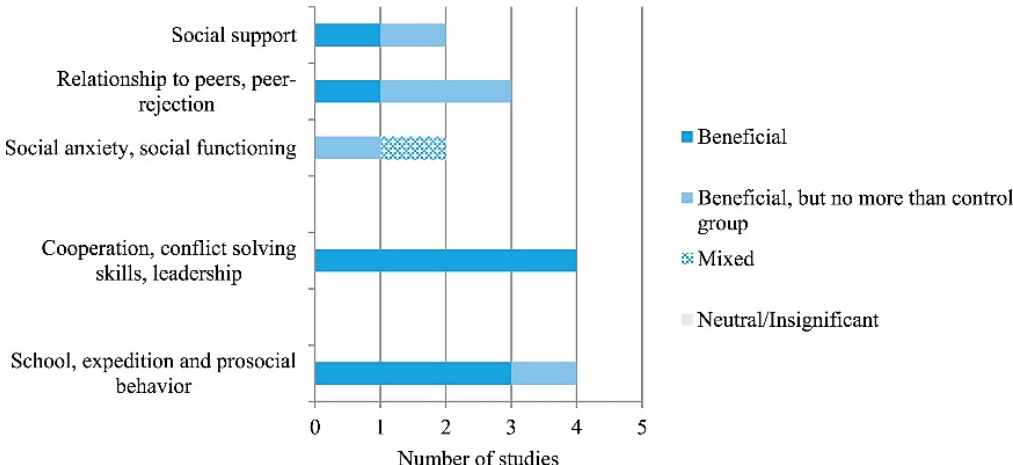


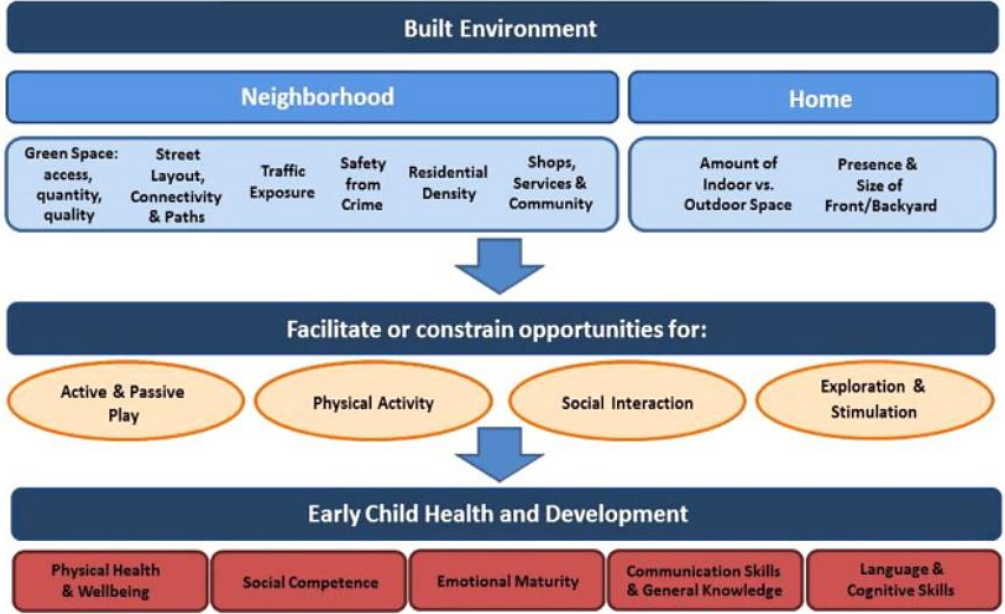
Mygind, L., Kjeldsted, E., Hartmeyer, R., Mygind, E., Bølling, M., & Bentsen, P. (2019). Mental, physical and social health benefits of immersive nature-experience for children and adolescents: A systematic review and quality assessment of the evidence. *Health & Place*, 58, 102136.

Fig.2

Overview of mental health outcomes and results.



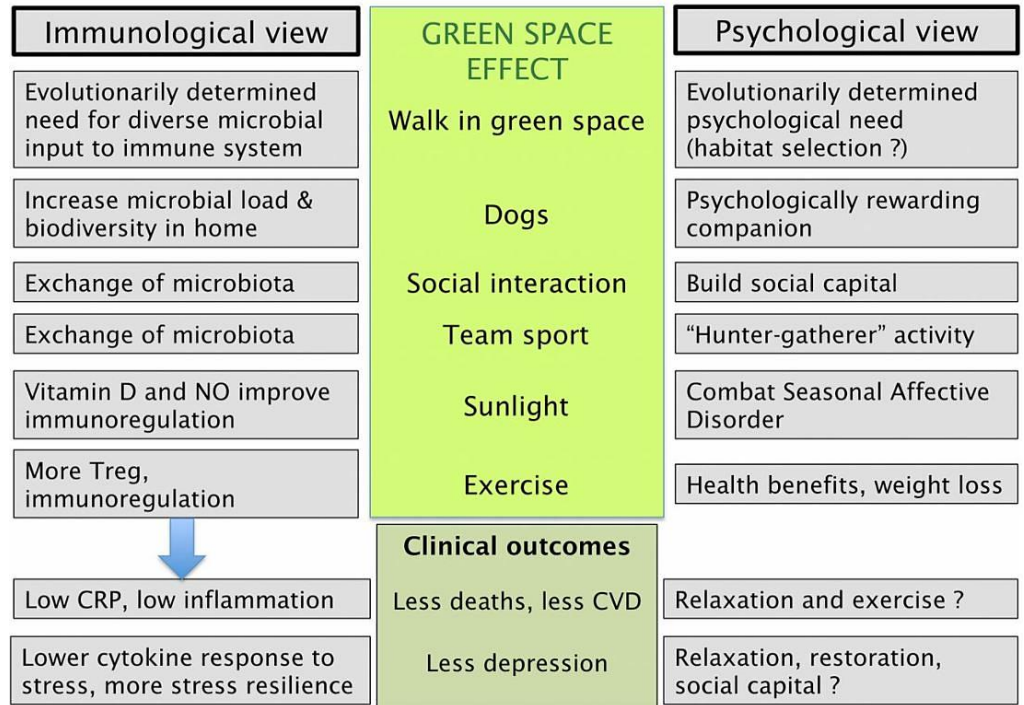
<p>Mygind, L., Kjeldsted, E., Hartmeyer, R., Mygind, E., Bølling, M., &amp; Bentsen, P. (2019). Mental, physical and social health benefits of immersive nature-experience for children and adolescents: A systematic review and quality assessment of the evidence. <i>Health &amp; Place</i>, 58, 102136.</p>	<p>Fig.3</p>	<p>Overview of social health outcomes and results.</p>  <table border="1"> <caption>Data for Fig.3: Overview of social health outcomes and results</caption> <thead> <tr> <th>Outcome</th> <th>Beneficial</th> <th>Beneficial, but no more than control group</th> <th>Mixed</th> <th>Neutral/Insignificant</th> </tr> </thead> <tbody> <tr> <td>Social support</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> </tr> <tr> <td>Relationship to peers, peer-rejection</td> <td>1</td> <td>2</td> <td>0</td> <td>0</td> </tr> <tr> <td>Social anxiety, social functioning</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> </tr> <tr> <td>Cooperation, conflict solving skills, leadership</td> <td>4</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>School, expedition and prosocial behavior</td> <td>3</td> <td>1</td> <td>0</td> <td>0</td> </tr> </tbody> </table>	Outcome	Beneficial	Beneficial, but no more than control group	Mixed	Neutral/Insignificant	Social support	1	1	0	0	Relationship to peers, peer-rejection	1	2	0	0	Social anxiety, social functioning	0	1	1	0	Cooperation, conflict solving skills, leadership	4	0	0	0	School, expedition and prosocial behavior	3	1	0	0
Outcome	Beneficial	Beneficial, but no more than control group	Mixed	Neutral/Insignificant																												
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<p>Christian, H., Zubrick, S. R., Foster, S., Giles-Corti, B., Bull, F., Wood, L., ... &amp; Boruff, B. (2015). The influence of the neighborhood physical environment on early child health and development: A review and call for research. <i>Health &amp; place</i>, 33, 25-36.</p>	<p>Fig.1</p>	<p>Model of how the neighborhood physical environment may facilitate or constrain healthy child development.</p>  <pre> graph TD     subgraph Built_Environment [Built Environment]         subgraph Neighborhood             GS[Green Space: access, quantity, quality]             SL[Street Layout, Connectivity &amp; Paths]             TE[Traffic Exposure]             SC[Safety from Crime]             RD[Residential Density]             SSC[Shops, Services &amp; Community]         end         subgraph Home             IOS[Amount of Indoor vs. Outdoor Space]             PFS[Presence &amp; Size of Front/Backyard]         end     end      Built_Environment --&gt; FCO[Facilitate or constrain opportunities for:]          subgraph Opportunities [Facilitate or constrain opportunities for:]         AP[Active &amp; Passive Play]         PA[Physical Activity]         SI[Social Interaction]         ES[Exploration &amp; Stimulation]     end          Opportunities --&gt; ECHD[Early Child Health and Development]          subgraph ECHD_Outcomes [Early Child Health and Development]         PHW[Physical Health &amp; Wellbeing]         SC[Social Competence]         EM[Emotional Maturity]         CS[Communication Skills &amp; General Knowledge]         LCC[Language &amp; Cognitive Skills]     end </pre>
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Rook, G. A. (2013). Regulation of the immune system by biodiversity from the natural environment: an ecosystem service essential to health. *Proceedings of the National Academy of Sciences*, 110(46), 18360-18367.

Fig.4

Immunological and psychological explanations for the health benefits derived from contact with the natural environment. (NO, nitric oxide). There are many studies of exposures during the perinatal period that point to the immunological mechanisms, whereas most studies in adult life have been orientated toward psychological explanations, and have not included investigation of the immunoregulatory aspects.



Shanahan, D. F., Fuller, R. A., Bush, R., Lin, B. B., & Gaston, K. J. (2015). The health benefits of urban nature: how much do we need?. *BioScience*, 65(5), 476-485.

Fig.1

Examples of the dose–response relationship between nature and measures of health or well-being from previous studies; (a) psychological well-being (“reflection”) in response to exposure to different numbers of habitat types in Sheffield, United Kingdom (Fuller et al. 2007); (b) the relationship between green space cover (in a 3-kilometer radius around the home) and the percentage of respondents stating their health is “good” or better (adapted from Maas et al. 2006 to show the inverse of the data originally presented); (c) the change in stress levels in response to different landscape types (adapted from Beil and Hanes 2013 to show the inverse of the stress measure originally presented); (d) the change in mean arterial diastolic blood pressure over time during exposure to urban and natural settings in California (adapted from Hartig et al. 2003 to show only the first section of the experiment where participants were not exercising).

Figure 1.

