Appeal No. 21-2449

IN THE UNITED STATES COURT OF APPEALS
FOR THE SEVENTH CIRCUIT

PROTECT OUR PARKS, INC., *et al.*,
Plaintiffs-Appellants,

v.

PETE BUTTIEGIEG, SECRETARY OF THE U.S. DEPARTMENT OF TRANSPORTATION, *et al.*,
Defendants-Appellees.

Appeal from the United States District Court
for the Northern District of Illinois
Hon. Robert Blakey
1:21-cv-02006

MOTION FOR LEAVE BY TERESA H. HORTON, PhD TO FILE A BRIEF AS *AMICUS CURIAE* IN SUPPORT OF PLAINTIFFS' APPEAL FROM THE DENIAL OF THEIR REQUEST FOR A PRELIMINARY INJUNCTION

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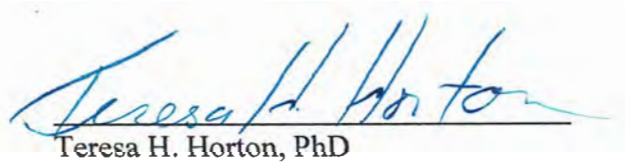
CORPORATE DISCLOSURE STATEMENT AND NOTIFICATION OF PUBLICLY HELD AFFILIATES

Amicus curiae is an individual.



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I, Teresa H. Horton, PhD respectfully request leave to file the accompanying *amicus curiae* brief attached as Exhibit A in support of Plaintiffs' appeal of the denial of their requires for a preliminary injunction ruling. Information regarding Teresa H. Horton, PhD is attached as part of the appendix to the brief. The motion should be granted for the following reasons:

1. The Court has previously allowed *amici curiae* when addressing an earlier motion before this Court. Consistent with the allowance of these *amici,* the Court should exercise its discretion and permit Teresa H. Horton, PhD to submit the attached *amicus* in support of the Plaintiffs' appeal from the denial of the Plaintiffs' motion for preliminary injunction.

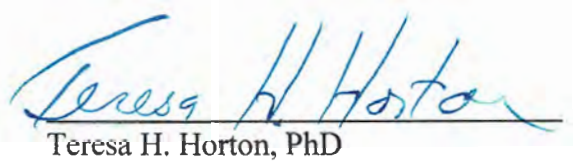
2. Dr. Horton has strong interests in the case in the same fashion that other *amici* have exhibited, and meets the requirements for filing an *amicus curiae* brief.

Teresa H. Horton, PhD is a biologist by training and is currently Associate Professor of Research in the Evolutionary and Ecological Approaches to Health and Development research group in the Department of Anthropology at Northwestern University. Her research investigates biological and psychological mechanisms by which environmental exposures impact health and wellbeing. This brief represents Dr. Horton's personal expert opinion of the existing scientific data and does not represent the views of Northwestern University. In addition, the history and work done by Dr. Horton gives her unique knowledge and perspectives in regards to urban landscapes generally and their impact on human health.

3. Dr. Horton agrees with Plaintiffs that their request for a preliminary injunction should have been granted and the trial court's decision should be reversed. *Amicus curiae's* proposed brief does not duplicate the arguments made by Plaintiffs as to why the Court should reverse the decision by the District Court denying the injunction. Instead, the proposed *amicus curiae* brief provides the Court various details and context that that have not been discussed and which further support denial of the Defendants' motion.

Dated: 24 September 2021

Respectfully submitted,



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CERTIFICATE OF SERVICE

I certify that, a true and correct copy of the foregoing was filed with the Clerk of the United States Court of Appeals for the Seventh Circuit via third party commercial carrier for overnight delivery on September 24, 2021. Electronic copies will be emailed to the following parties:

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4. No party or counsel for a party authored the attached brief in whole or in part, and no person other than *amicus curiae* contributed any money to fund its preparation or submission. The *amicus curiae* is not a subsidiary or affiliate of any publicly owned corporation.

5. This motion and attached brief are timely, as it is filed "not later than 7 days after the principal brief of the party being supported is filed." *See* Fed. R. App. P. 29(a)(6)

6. No party would be prejudiced by the filing of this *amici curiae* brief. For the foregoing reasons, Teresa Horton's motion for leave should be granted, and the *amicus curiae* brief attached as Exhibit A should be filed.

Dated: 24 September 2021

Respectfully submitted,

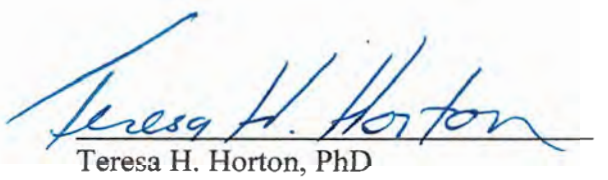

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EXHIBIT A

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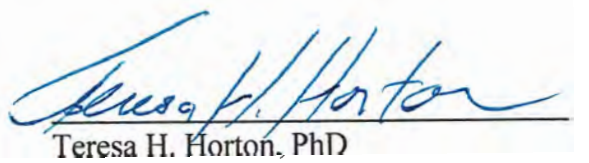

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TABLE OF CONTENTS

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INTEREST OF AMICUS CURIAE

Teresa H. Horton, PhD is a biologist by training with over 35 years of experience conducting research on the neural and endocrine mechanisms by which human and non-human animals adapt to their environment (Appendix 1: *Curriculum Vitae*). Dr. Horton has spent the past six years researching the impact of urban greenspace, including trees, on the psychological and physiological health of humans. This research has included observational studies and randomized controlled experiments. Dr. Horton has published peer-reviewed original research and review papers on the impact of urban greenspace on human health and health disparities.[2-11] She is currently Associate Professor of Research in the Evolutionary and Ecological Approaches to Health and Development research group in the Department of Anthropology at Northwestern University. She founded and leads the Nature, Culture, and Human Health Network (NCH2) and is a member of the Scientific Advisory Committee of the Illinois Chapter of The Nature Conservancy. This brief represents Dr. Horton's personal expert opinion of the existing scientific data on the impact of urban greenspaces on human health and wellbeing and does not represent the opinions of Northwestern University, NCH2, or The Nature Conservancy.

No party or counsel for a party authored the attached brief in whole or in part, and no person other than *amicus curiae* contributed any money to fund its preparation or submission. The *amicus curiae* is not a subsidiary or affiliate of any publicly owned corporation.

ARGUMENT

Individual and Community Health Benefits of Urban Greenspace

An increasingly large body of literature points to the health promoting effects of access to

Individual and Community Health Benefits of Urban Greenspace

An increasingly large body of literature points to the health promoting effects of access to nature.[5,12,13] Engagement with nature can influence health and wellbeing through multiple physiological and psychological mechanisms by evoking nervous, endocrine, and immune system responses. Stress reduction, cognitive restoration, and opportunities for physical activity are well documented effects of nature engagement.[5]

Engagement with high quality landscapes that include diverse vegetation, including trees, natural sounds (e.g. bird song, flowing water), and water elements provide mental restoration, improved cognitive function, reductions in perceived stress and anxiety, and improvements in objective biological markers of stress.[5,7,9-18] Access to urban greenspace is associated with improved physical health outcomes including, but not limited to, improved blood pressure, HDL ("bad") cholesterol, and lower prevalence of Type 2 Diabetes.[15] Additionally, access to greenspace is associated with reductions in domestic and community violence, including reductions in gun violence and increased community cohesion.[19-21]

Health Disparities: Count the trees

Residents of non-White dominated and low-income census tracts (e.g. the Woodlawn neighborhood

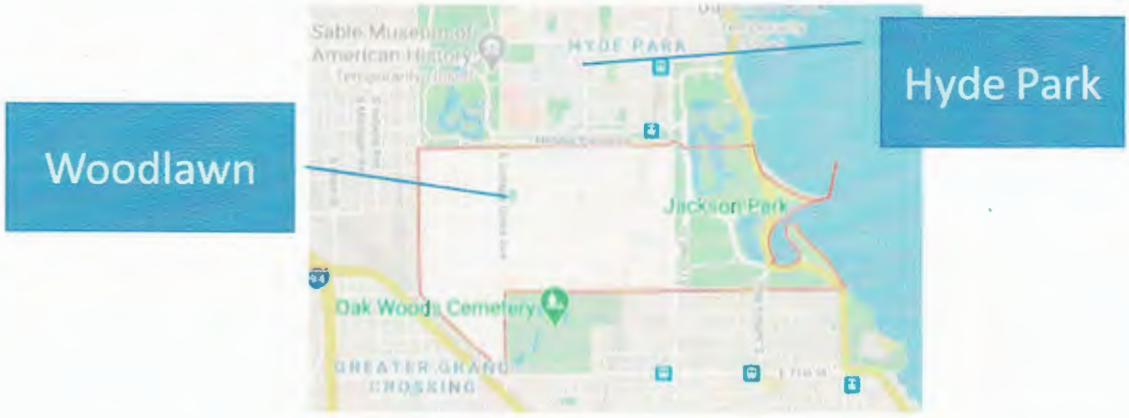

Figure 1. Map showing location of the Woodlawn and Hyde Park neighborhoods of Chicago. Both neighborhoods are adjacent to Jackson Park.

neighborhood. Figure 1).[22] Specifically the life expectancy of Woodlawn residents is seven years shorter than that of residents of the adjacent neighborhood of Hyde Park (Figure 1).[23] Residents of White-majority census tracts in Chicago generally have significantly greater access to urban greenspace than to residents of minority-dominated census tracts.[24] This disparity is illustrated in aerial photographs of Woodlawn and Hyde Park (Figure 2).[1]

Epidemiological studies of populations world-wide document that people who live near urban greenspace enjoy better self-reported health, lower mortality, lower incidence of Type 2 Diabetes, and lower rates of preterm births and births of babies that are small for their gestational age; statistics that hold up when corrected for wealth, education, and other demographic factors.[15] However, not all greenspace is created equal.[25]

Figure 2. Photograph from Riley (2012).[1] Aerial photographs of the adjacent neighborhoods of Woodlawn and Hyde Park in Chicago, IL. Note the dense tree cover of Hyde Park as compared to Woodlawn.

Why mature trees matter

One concern for the planned Obama Presidential Center is the removal of large numbers of mature trees from Jackson Park. Although the plan for the Center calls for extensive landscaping and the planting of new trees, the removal of the existing mature trees will have negative impacts not only on the of the park that impact physical properties such as temperature, air quality, and the control of storm water runoff, but also on the characteristics that lead to psychological and physiological health benefits.[12,13,26-28]

Of particular concern is the loss of the cooling effects of the mature tree canopy resulting in increased heat island effects. Among other affordances, Jackson Park provides a cool refuge for local residents. Global climate change has led to increased temperatures extremes, which have negative impacts on human health and, as seen during recent heat waves, causing heat stress, heat stroke, and death.[26,28] A tree may take 50 or more years to reach a size sufficient to provide significant cooling. It also takes many trees to form a forest canopy. Although selective removal of diseased or damaged trees is essential for park and forest management, the clearcutting of trees at the Jackson Park site will have significant negative impacts on environmental quality.

Mature trees and complex landscapes that contain elements reflective of the geophysical and biological actions of nature have greater restorative impacts than simple or highly manicured landscapes.[14,25] Better health is also associated with areas that have lower levels of anthropogenic noise and higher levels of natural sounds (e.g. bird song, flowing water, wind in trees).[16] It is these restorative and salutogenic characteristics that will be lost by building the Obama Presidential Center in Jackson Park. Rather than meeting the objective of reducing health disparities, the Obama Presidential Center may in fact increase them.

CONCLUSION

This presentation is a brief selection of the evidence for the health benefits of nature and the rationale for maintaining the mature trees that already exist in Jackson Park. Residents should not be asked to wait 50 years to regain the benefits of the mature trees that already exist in Jackson Park. The Obama Foundation should be encouraged to seek alternative sites where Center could contribute to the expansion of much-needed urban greenspace.

Dated: 24 September 2021

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APPENDICES

Appendix 1. Curriculum vitae of Teresa H. Horton

Curriculum Vitae

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ORCID ID 0000-0002-3734-8065

Research Summary:

As an environmental physiologist, I am an interdisciplinary scientist. I use the principles of anthropology, behavioral endocrinology, ecology, evolution, neuroscience and physiology to investigate the mechanisms by which organisms adapt to their environment. My early work focused on the neural and endocrine mechanisms by which rodents adapt to seasonal changes in day length, temperature, and energy availability; mechanisms that enable animals to be flexible in the face of environmental change. Because increasing numbers of humans live in urban areas, experience the chronic stresses of urban life, and suffer the diseases of chronic stress, I have begun to apply similar techniques and paradigms to investigate humans and the physiological and behavioral responses to their environment. My current research uses biomarkers and psychological assessments to test the hypothesis that access to natural landscapes contributes to improved health, wellbeing, and resilience of humans by offering an escape from the stressors of urban life.

Education

B.S. Zoology, 1979	University of Washington, Seattle, Washington (with College Honors)
PhD. Biology, 1984	University of Utah, Salt Lake City, Utah. (Dissertation: *Variability in Responses to Photoperiod by the Vole*).
Postdoctoral Fellow 1984-1986	Department of Neurobiology and Physiology, Northwestern University (Reproductive endocrinology, with Dr. Neena B. Schwartz)
Postdoctoral Fellow 1986-1989	School of Life and Health Sciences, University of Delaware (Comparative endocrinology, with Dr. Milton H. Stetson)

Honors and Awards

1982-83 University Research Fellow, University of Utah

1991 Kent State University, Research and Creative Activities Award. Fall Semester

Professional Experience/Appointments

1979 Stipendium für Auslander (support for foreign visitor), Max Planck Institut für Verhaltensphysiologie, Abteilung Aschoff, Federal Republic of Germany. (Research Associate to Dr. K. Hoffmann, Summer).

1990- 94 Assistant Professor, Kent State University, Kent, OH.

1993-94 Visiting Scholar, Department of Neurobiology and Physiology, Northwestern University, Evanston, IL

1994-04 Research Neurobiologist/Assistant Professor, Department of Neurobiology and Physiology, Northwestern University, Evanston, IL

1994-pres. Member. Center for Reproductive Science. Northwestern University.

1995-2000 NSF Science and Technology Center: Center for Biological Timing. A consortium including faculty from the University of Virginia, Northwestern University, Rockefeller University, and Brandeis University. (Center closed in 2000, end of 10 yr. limit imposed by NSF)

1996-2000 Asher Center for the Study and Treatment of Depressive Disorders, Department of Psychiatry and Behavioral Sciences, Northwestern University Medical School.

1996-2014 Lecturer, Undergraduate Program in Biological Sciences, Weinberg College of Arts and Sciences, Northwestern University, Evanston, IL (50% appointment)

2004-2010 Research Neurobiologist/Associate Professor (promotion), Department of Neurobiology and Physiology, Northwestern University, Evanston, IL

2000-pres Member. The Center for Sleep and Circadian Biology. Northwestern University.

2004-2013 Director, Science and Engineering Research and Teaching Synthesis (SERTS)

2005-2013 Director, Interdisciplinary Committee on Evolutionary Processes (ICEP)

2011-12 Research Associate Professor. Department of Physiology, Feinberg School of Medicine, Northwestern University, Chicago, IL. (50% appointment)

2012-2014. Research Associate Professor. Department of Anthropology, Human Biology, Northwestern University, Evanston, IL. (50% appointment)

2014-2015 Research Affiliate. Department of Anthropology, Human Biology, Northwestern University, Evanston, IL (unpaid position).

2015-present Associate Professor of Research. Department of Anthropology, Human Biology, Northwestern University, Evanston, IL (50% 2015-2016; 100% 2016-present).

Teaching Experience

Kent State University: Human Physiology, Introductory Biology Laboratory, Endocrinology, Graduate Seminar on Circadian Rhythms

Northwestern University: Freshman seminars (Biol Sci 101-6 and 102-6), Human Reproduction (Biol Sci 160), Reproduction and the Environment (General Studies, 380-7), Biological Clocks (Biol Sci 124), Environmental Biology (Biol Sci 204), Biology in the Information Age (Biol Sci 101-0), Animal Behavior (Biol Sci 320), Endocrinology (Biol Sci 356), Capstone Seminar in Evolutionary Processes (Biol Sci 397), Neuroendocrine Basis of Metabolic Disorders (NUIN 499)

Undergraduate Advising Experience

Program in Biological Sciences, Northwestern University. Biological Sciences Majors, Physiology and Neuroscience Concentration.

WCAS, Freshman Advisor, including service in the pilot program for the First Year Experience Project.

Other Special Roles

Fellow	Women's Residential College, Northwestern University. 2012-2017.
Director	Interdisciplinary Committee on Evolutionary Processes (ICEP) and the associated Minor in the Study of Evolutionary Processes. 2005-2011.
Director	Science and Engineering Research and Teaching Synthesis Program (SERTS). 2008-2012.

Graduate Students Supervised

1991-93	M.S., Kristina M. Stanfield. Kent State University (PhD, London School of Hygiene and Tropical Medicine, 2013)
1993-94	M.A., G. Richard Robusto. M.A. Kent State University (D.O. Ohio University, 1999)
1997-98	M.S., Min Byong Kyoung
1998-99	M.S., Monica Sierszulski, Jeremy Vanburen, Viktor Tsirline (M.D.),
2001	Ph.D., Daniel Kolker (co-advised with Dr. Fred Turek).
2002	Ph.D., Sonali Anand (co-advised with Dr. Fred Turek).
2005	Ph.D., Brooke Miller (co-advised with Dr. Joseph Takahashi)
2005	M.S., Aisha Kung, (DVM)
2010	MS, Amy Flowers (Masters in Biotechnology, co-advised with Dr. Jon Levine)

Other Graduate Student Committees

2015 MPH Students, Culminating Experience Committee Member for three students (Morgen K. Hoke, Amber Kofman, and Sarah R. Taylor)

2019-pres PhD Student. Katherine Varey. Erikson Institute/Loyola University

Undergraduate Independent Study Students Supervised

1985-94 Twelve students (Institutions other than NU)

1993-06 Twenty-two students through August 2006 (Program in Biological Sciences, NU)

2006-07 Patrick Ahearn, Rebecca Poliwka

2007-08 Jamie L. White, Kalen Rimar, Jennifer Taylor

2007-09 Jennifer E. Taylor (Winner of the David Shemin Prize Basic Research)

2009-10 Charles Muller, Katherine M. Swanson (Ms. Swanson is a student at the College of William and Mary, she is working on a collaborative project with Dr. Paul Heideman, Professor of Biology, College of William and Mary, and me. She received a very prestigious Monroe Scholorship from the College of William and Mary to work on this project at NU in the summer of 2010.).

2016-17 Hollyn Cetrone, Annie J. Lee

2017-18 Hollyn Cetrone

Society Memberships

Child and Nature Network

Human Biology Association

Society for Behavioral Neuroendocrinology

Grants Received

1982 National Science Foundation, Dissertation Improvement Grant in Population Biology and Ecological Physiology, $6,500.

1986 The Alumnae of Northwestern University Research Grant, $2,500.

1987 National Research Service Award. National Institute of Child Health and Human Development. $25,000.

1990 Biomedical Research Support Grant (Kent State University). $1750.00

1991 Biomedical Research Support Grant (Kent State University). $1017.00

1992 National Science Foundation. Investigations into the mechanism of maternal transfer of photoperiodic information. Period: 4/93-3/95 (Extended to 9/96). Total award $156,000.

1993 William and Flora Hewlett Foundation. Integrated Universtiy Research Teams in Multiple Departments to Teach Science at Introductory Level to Undergraduate Students. Total award $150,000. (Co-PI with Fred Turek).

1997 **NIH R01 HD-09885-21** (PI: Turek, F.W., Horton, Co-PI). Photoperiodic control of reproduction: effects of age. 06/30/76-6/30/01. $148,097.Annual Direct Costs.

1994 **NIH P01 AG 11412** (Project Director: Van Cauter, E. Project 3. Turek, F.W. PI, Horton, Co-PI). Alterations in Circadian Timing in Aging- Project 3 - Altered Rhythms & Aging: Mechanism & Restoration of Function. 12/01/97-11/30/02. $191,757 Annual Direct Costs.

1995 **NIH P01 HD-21921-11** (Project Director: Mary Hunzicker-Dunn) (Project 1. Co-PI with Turek, F.W.). FSH: Control and Action. 12/01/98-11/30/03. $115,545 Annual Direct Costs.

1996 Science and Engineering Research and Teaching Synthsis. A Cross School Initiative. Deans of Northwestern University. T. H. Horton, PI, T.O. Mason, Co-PI. 03/01/99-04/30/02. $20,000 Annual Direct Costs.

2000 **L/MH/AG/NS/64147 (**PI: Turek, F.W., M.H. Vitaterna, Co-PI, Horton, collaborator). Stress Effects on Sleep: Influence of Genes and Gender. 9/30/99-9/29/03. $225,000 Annual Direct Costs.

2002 **Merck & Co.** (PI: T.H. Horton, B.C. Woods and F.W. Turek, co-investigators). The influence of a neuropeptide Y Y5 receptor antagonist on photic and non-photic input to the circadian pacemaker. 6/01/02-02/01/05

2002 **P50 HD44405-01** NIH/NICHD, (Center Director A. Dunaif, Center Co-Director: J. Levine; T. Horton – Key Personnel) 9/1/02-8/30/07; Specialized Center of Research: Gender Issues Affecting Women's Health, Project IV: Effects of Androgens on Female Reproduction

2007 **P50 HD44405-06** NIH/NICHD, (Center Director A. Dunaif, Center Co-Director: J. Levine; T. Horton – Co-Investigator) (9/1/07-8/30/12). Specialized Center of Research: Gender Issues Affecting Women's Health, Project IV: ANDROGENIC PROGRAMMING OF NEUROVISCERAL CONTROL SYSTEMS

2007 **R03 AG030181-01 NIH/NIA** (PI J. E. Levine, Investigator T. H. Horton**)** "Disregulation of Potassium Channels in Menopausal Hot Flashes". 04/01/07-03/31/09

2011 **R15 HD068962-01 (**PI. P.D. Heideman, Investigator T.H. Horton). 04/01/2011-03/31/2014. Combinatorial contributions of heritable neuroendocrine variation to male infertility.

2015 **NCCP 15-10-001.** Forest Preserves of Cook County (PI. T.H. Horton). 12/01/2015-11/30/2016. Walking Green: Developing an evidence-base for Nature Prescriptions.

2016 **University of Minnesota,** Grant in Aid of Research. (PI. Mark Pereira, Dept. of Epidemiology, University of Minnesota; Horton primary collaborator). Walking Green: Developing an evidence-base for Nature Prescription. The GIA provides support for establishing a new research collaboration on the health benefits of nature which extend the Walking Green project to older adults.

2016-21 **The Negaunee Foundation.** Salary and additional research support for Walking Green.

2019-24 **NIH R01CA239187-01** NIH/Time-sensitive Obesity Policy and Program Evaluation, PAR-15-346. (PI. Amber L. Pearson, Department of Geography, Environment, and Spatial Sciences, Michigan State University; Horton co-investigator). Impact of ecological park restoration hon health in low income neighborhoods: A natural Experiment. Total direct costs: $3,318,692.

2019 NU ARCC (Alliance for Research in Chicagoland Communities). (Principal Investigators: Teresa H. Horton (NU) and Daniel Hostetler (CEO, Above and Beyond). "Partnership Development Seed Grant: Above and Beyond Family Recovery Center Healing Garden".

2020 WCAS COVID-19 Seed Funding. T.H. Horton, PI. "Coping with COVID-19: Impact of Access To Nature On Health and Wellbeing."

2021-NU-ARCC Teresa H Horton (NU), David Victorson (NU) and Daniel Hostetler (CEO, Above and Beyond). "Gardening for Recovery and Optimal Wellbeing (GROW): A Feasibility Study of PhotoVoice as a Therapeutic Tool."

Grants Pending

R01 ES033093-01A1 (Horton, T.H. Pereira, M.A. MPIs) 12/01/2021-11/30/2026

NIH/NIEHS Annual Direct Costs $498,880 (Yr 1)

Effects of Walking in Greenspace and the Built Environment in Adults with Prediabetes: A randomized crossover trial.

The major goal of this project is to conduct a randomized crossover trial to compare differences in measures of physiological, psychological, air pollution, and cardiometabolic risk between walking interventions completed in green and urban spaces in adults with prediabetes.

Walder Foundation (RxN) (Horton, T.H.) 01/01/2022 – 08/31/2023

Nature, Culture, and Human Health (NCH2): Catalyzing Nature-based Solutions for Human and Public Health Annual Direct Costs $144,500 (Yr 1)

Currently an all-volunteer organization, the NCH2 Network seeks to re-structure to serve as a regional venue to convene conservation and healthcare entities to collaborate on developing and advocating for nature-based solutions that enhance or restore ecosystems at an appropriate scale to bring economic, social, and environmental benefits, including improved human well-being and biodiversity, to our communities. The major goals of the propose project are: 1) Assess the evidence needs of stakeholders and support pilot projects to acquire that evidence; 2) Co-educate the diverse community of stakeholders; and 3) Establish a formal organization for NCH2 with the capacity to solicit funding and support projects and programs.

Cigna Foundation (Horton, T.H.) 0/01/2022 – 01/31/2024

Co-Creating Culturally Competent Wellness Programs: Leveraging Nature and Physical Activity Preferences of Hispanic Participants

Total Direct Costs $139,753.00

A community-engaged project to address co-occurring mental and physical health challenges among low-income Hispanic residents of the city of Waukegan, IL will be developed. The program will leverage emerging evidence for the combined benefits of physical activity and time in nature. Physical activity and time in nature both reduce stress and improve health and well-being. The project will adhere to best practices of community-engaged programming and research. The proposed program will leverage the known mental health benefits of physical activity and time in nature to develop a culturally competent program to improve mental health while also monitoring risk factors for chronic non-infectious diseases such as diabetes. The program will be evaluated based on feasibility and acceptability measures, as well as impact on mental and metabolic health outcomes.

University, Professional and Public Service

Kent State University, Department of Biological Sciences

1990 Undergraduate Curriculum Committee

1991 Chairman Review Committee

1991 Ten Year Plan Committee

1991 Howard Hughes Undergraduate Science Initiative (Kent State University) Proposal Preparation Committee

1991-92 Graduate Studies Committee

1992 Search Committee -Human Physiology Position, Kent State University, Trumball Campus

Northwestern University

1994 Organizing Committee, Northwestern University Conference on Women in Science

1996 Educational Infrastructure Committee, Department of Neurobiology and Physiology, Northwestern University.

1997-98 UPBS, Lecturer Search Committee

2004 PBS Search Committee (Plant Ecologist Search for two joint positions with the Chicago Botanic Garden)

2006-09 SAHAS (Sexual Assault Hearing and Appeals System) Committee Member

2006-08 GFC Benefits Subcommittee

2007 Department of Anthropology, Medical Anthropologist Search Committee

2008-09 Chair, One Book One Northwestern (University-wide community reading project) The Reluctant Mr. Darwin

http://www.northwestern.edu/onebook/archive/2008-09/index.html

2008-09 Member, Planning Committee, Regional Conference "Motherhood and Success in Science and Engineering" (with University of Chicago and Northwestern University and several other co-sponsors)
http://www.regonline.com/builder/site/Default.aspx?eventid=723086

2010-13 Member, One Book One Northwestern Long-term Planning Committee.

2021-22 Member, One Book One Northwestern Program Committee. Book Selection: The Story of More: How We Got to Climate Change and Where to Go from Here.

Regional Committees

2015-pres Nature, Culture and Human Health (NCH2) Working Group. Chair of the Steering Committee. NCH2.org

2015-pres Forest Preserves of Cook County, Next Century Conservation Plan, People Committee. http://nextcenturyconservationplan.org/technical-report/technical-report-goal-2/

2016-2017 Chicago Wilderness Association. Beyond the Choir Focus Group.
http://www.chicagowilderness.org/page/BeyondtheChoir

National Committees and Scientific Advisory Panels

1985 Society for the Study of Reproduction, Trainee Affairs Committee.

1988 American Society of Mammalogists. Ad-hoc Committee on Animal Husbandry Protocols.

1990-96 American Society of Mammalogists. Program Committee. (Chair from 1992-1996)

1992-94 American Society of Mammalogists. 75th Anniversary Committee.

1996 Society for Research on Biological Rhythms. Nominating Committee.

1996-98 American Society of Mammalogists. Animal Care and Use Committee

1996-98 American Society of Mammalogists. Honoraria Committee

1999-03 Society for Behavioral Neuroendocrinology, Education Committee (Committee member 1999-2003, chair 2001 – 2003)

2000 SENCER (Science Education for New Civic Engagements and Responsibilities) Faculty Working Group. Association of American Colleges and Universities.

2007-09 Society for Behavioral Neuroendocrinology, Information Technology Committee, Chair

2010 EPA -Federal Insecticide, Fungicide and Rodenticide Act Scientific Advisory Panel (FIFRA SAP, 4/26-30/2010 panel). "Re-evaluation of Human Health Effects of Atrazine"

2010-13 Society for Behavioral Neuroendocrinology, Treasurer

2010 & 11 NSF- Proposal Review Panelist. Modulation Panel, Neural Systems Cluster.

2017-present Physical Activity Research and Policy Network (Nature working group). https://www.cdc.gov/nccdphp/dnpao/division-information/policy/physicalactivity.htm

2018-present ParkRxAmerica.org Advisory Board (https://parkrxamerica.org/about.php)

2020-present The Nature Conservancy. Consultant for the Nature and Human Health Toolkit Project (Rachel Holmes, TNC Urban Forestry Lead, project leader).

2020-present The Nature Conservancy. Illinois Chapter Science Advisory Committee.

2021-present The SHIFT Summit. Program Committee Co-Chair

Consulting Reviewer for the Following Agencies and Journals: American Journal of Physiology, Biology of Reproduction, Brain Research, International Journal of Environmental Research and Public Health, Journal of Biological Rhythms, Journal of Mammalogy, Journal of Neuroendocrinology, Journal of Reproduction and Fertility, Laboratory Animal Science, Landscape and Urban Planning, National Science Foundation

Guest Editor: International Journal of Environmental Research and Publich Health. Special issue titled Evidence for Incorporating Green Exercise into Clinical and Public Health Practice

Community Service: Chiaravalle Montessori School- (2000-2001 Roomparent, 2001-2002 Diversity Committee Member); Charles G. Dawes Elementary School PTA- Science Saturday Volunteer, (workshops on DNA extractions and the Wild Mammals of Evanston 2002-2006 for 3-5th graders), Treasurer (2005-2007). The Musical Offering Community Music School - Parent Volunteer (2005-2011), Board of Directors (Secretary (2011-2013), President (2013-2014))

Invited Presentations (since 2000):

2004 **The Human Biology Association.** Symposium on Fetal Origins of Developmental Plasticity. **Title of Talk:** Fetal origins of developmental plasticity: Animal models of induced life history variation. (Link to symposium volume in J Human Biol http://www3.interscience.wiley.com/journal/109859428/issue)

2009 **American Aging Association's 38th Annual Meeting and 23rd Annual Meeting of the American College of Clinical Gerontology:** Integrative Biology: Hormones, Signaling and Aging. Phoenix, AZ. Session title: Evolution, Development and Clinical Issues in Aging and Age-related Disease. **Title of talk:** The Thrifty Mother Hypothesis: an Evolutionary View of Aging, Energy and Estrogen. (Link to Program http://www.americanaging.org/2009_Final_Program.pdf)

2014 **Nature, Culture, and Human Health.** Where's the Tree: Identifying the Effects of Nature. The Chicago Botanic Garden, Glencoe, IL. December 18, 2014. Title: **https://www.slideshare.net/secret/2B3ACAIt8jV29Q**

2016 **University of Illinois Extension. Annual Conference.** I Hotel and Conference Center, Urbana, IL. November 16-17, 2016

2018 **Dupage Environmental Summit.** The Conservation Foundation. Northern Illinois University, Naperville, IL. Title: Where's the Tree? https://www.youtube.com/watch?v=W2kBaXt22LM&feature=youtu.be

2018 **Institute for Cultural Affairs.** Chicago IL. Green and Blue for Better Health. February 27, 2018

2018 **Swedish Covenant Hospital,** Grand Rounds. Chicago, IL. April 26, 2018. Title: Walking Green: Developing an Evidence-base for Green Prescriptions.

2019 **University of Illinois Conservation at Home Conference.** Building an Evidence BAsde for Nature Prescriptions: Why we need data. Chicago Botanic Garden. March 2, 2019.

2019 **Barrington Area Conservation Trust.** Nature Rx. How spending time in nature is good for our mind, body, & soul! Barrington White House, Barrington, IL. October 30, 2019.

2020 **Illinois Master Naturalist Conference.** Keynote address. The Health of Humans and Nature: A two-way street. Online. October 5-9, 2020. https://extension.illinois.edu/sites/default/files/2020_mn_conference_agenda_1.pdf

2020 **Greentown Conference.** Urban Forestry: Can Nature Be Medicine? (with V. Kyle, C. O'Leary, A. De Reu, and M. Custic). Online. September 23 and 30, 2020. https://www.greentownconference.com/presentations

2020 **GP RED Think Tank.** Developing the New Normal: Green/Open Space Standards for the Future (with Dr. R. Layton). Online. November 17-20, 2020. https://whova.com/web/grntt_202011/

Meeting Presentations since 2000:

2000 Anand S., Turek F.W., **Horton T.H.** Social stimulation of luteinizing hormoen (LH) secretion in male Siberian hamsters: nature of the stimulus and potential neural pathways. Joint meeting of the 6th International Converence on Hormones, Brain and Behavior & the Society for Behavioral Neuroendocrinology. Madrid, Spain. Abstract #P4-27.

2000 Anand S., Turek F.W., **Horton T.H.** Do female pheromeones induce male Siberian hamsters to secrete luteinizing hormone (LH)? Soc Neurosci. Abstr, Vol 26, Part 1, p. 2200.

2001 Anand S., Turek F.W., **Horton T.H.** Does stress alter female-induced luteinizing hormoen (LH) release in male Siberian hamsters? Fifth Annual meeting of the Society for Behavioral Neuroendocrinology, Tempe, AZ.

2002 Anand S., Carr V.M., Turek F.W., **Horton T.H.** The olfactory toxicant, dichlobenil, eliminates female-induced luteinizing hormone (LH) release in male Siberian hasmters. Sixth Annual meeting of the Society for Behavioral Neuroendocrinology. Amherst, MA.

2003 Miller B.H., Olson S.L., Turek F.W., **Horton T.H**., Takahashi J.S. Reproductive defects in the *Clock* mutant mouse. Program No. 924.11 Society for Neuroscience.

2008 **Horton T.H.,** White, J.L., Oeser M.L., Levine, J.E. Chronic peripheral and rapid central effects of estrogen on tail skin temperature in ovariectomized mice. Endocrine Society 90th Annual Meeting, San Francisco, CA.

2009 **Horton T.H.** and Levine, J.E. Estrogen, Ion Channels, and Thermoregulation: From Hot Flashes to Hibernation. American Society of Mammalogists Annual Meeting. Fairbanks, AK. 24-28 June, 2009.

2013 **Horton T.H.,** Oeser M.L., Levine, J.E. Association of Estrogen Receptor Alpha and the Two-pore Potassium Channel TREK-1 in the Hypothalamus of Female Mice. The 17th Annual meeting of the Society for Behavioral Neuroendocrinology, Atlanta, GA.

2017 **Horton T.H.**, Berman M.G., Cetrone H., Koselka E., Lee A.J., Leonard W.R., Norman G.J., and Smith K.E.L. Walking Green: Developing an Evidence Base for Nature Prescriptions. Natural Capital Symposium. Stanford University. Palo Alto, CA. 20-23 March 2017. http://www.naturalcapitalproject.org/natcap2017/

2018 Koselka, E., Lee, A., Cetrone, H., Minasov, A., Leonard, W.R., and **Horton, T.H.** Green Exercise Improves Mood and Reduces Anxiety. Annual Meeting of the Human Biology Association. Austin, TX. 11-12 April, 2018.

2018 **Horton, T.H**., Koselka, E.P.D., Lee, A.J., Cetrone, H.M., Minasov, A., Leonard, W.R., Pereira, M.A., Nogueira De Brito, J., Larson, J.M. Schneider, I.S. Lessons Learned: Implementation of longitudinal studies of green exercise. International Congress on Integrative Medicine & Health. Baltimore, MD. 8-11 May, 2018.

2019 **Horton, T.H.,** E.P.D. Koselka, A. Minasov, L. Weidner, H.M. Cetrone. (2019). Activity and Fasting Blood Glucose: Location, Location, Location. Active Living Research Conference 2019. Charleston, S.C. February 17-20, 2019

2019 de Brito Nogueira, J., Pope, Z.C., Mitchell, N., Schneider, I.E., **Horton, T.H.,** Pereira, M.A. Changes in psychological state measures after green versus suburban walking exercise: a pilot crossover study. American College of Sports Medicine Annual Meeting 2019. Orlando, FL, May 28-June 1, 2019.

2019 Pope Z.C., Brito J.N., Mitchell N.R., Schneider I.E., **Horton T.H.,** Pereira M.A. (2019) Heart rate variability differences between green and suburban walking: a pilot crossover study. Circulation. 2019; 139(Suppl 1):AP099. doi: 10.1161/circ.139.suppl_1.P099. American Heart Association EPI|Lifestyle Conference 2019. Houston, TX, March 5-8, 2019.

2019 **Horton, T.H.** and Minasov, A. (2019). Green exercise improves fasting blood glucose. SHIFT: Nature as Medicine. The Business Case. Jackson, WY. October 16-18, 2019.

2019 Schultz, C.L., **Horton, T.H.**, Henderson, J., Scribner, M., Faison, D., Zarr, R. (2019) A protocol for school-based park prescriptions: Connecting students to nature. SHIFT: Nature as Medicine. The Business Case. Jackson, WY. October 16-18, 2019.

2020 Victorson, D.E., Barrett, B.P. and **Horton, T.H.** (2020). Hot Topic Panel. Eco-Wellness: Connection, Health, and Preservation of Mind, Body, and Soil. International Congress of

Integrative Health and Medicine. Cleveland, OH (April 28-May 1) – Meeting Cancelled due to COVID-19.

2020 **Horton, T.H.,** Yang, M., Poole, Ol, Minasov, A., Murphy,C., Salvidio K., and Green, A. Jobs in the Garden (JIG): an Evaluation of the Chicago Botanic Garden Veteran Internship Program (VIP). SHIFT Summit: Healthy by Nature. Jackson, WY (Online). October 14-16, 2020.

2020 Minasov, A., Weidner, L., and **Horton, T.H.** Walking Green II. Lessons Learned from Repeated Measures Experiments of Green Exercise. SHIFT Summit: Healthy by Nature. Jackson, WY (Online). October 14-16, 2020.

Symposia Organized (Since 2010)

2014 **Horton, T.H., Geraghty, C., and Benveniste, P.** *Nature, Culture, and Human Health*. The Chicago Botanic Garden, Glencoe, IL. December 18, 2014. https://www.chicagobotanic.org/nch2/2014

2016 **Horton, T.H., Geraghty, C., and Benveniste, P.** *Partners in Mental Health: Veterans, Therapists, and Nature*. A project of Nature, Culture, and Human Health. Location: The Chicago Botanic Garden, Glencoe, IL. February 16, 2016. https://www.chicagobotanic.org/nch2/2016

2018 Kreski, B., Game, C., Gomez, V., Lewis, K., and **Horton, T.H.** *Nature: Stress' Antidote.* A project of Nature, Culture, and Human Health. Location: The Chicago Botanic Garden, Glencoe, IL. October 15, 2018. https://www.chicagobotanic.org/nch2/symposium/agenda

Publications (in reverse chronological order)

59. Christiana, R., G. M. Besenyi, J. Gustat, T. H. Horton, T. L. Penbrooke and C. L. Schultz (2021). "A scoping review of the health benefits of nature-based physical activity." Journal of Healthy Eating and Active Living **1**: 142-160. http://profpubs.com/index.php/jheal/article/view/25/50

58. Pearson, A. L., **T. Horton**, K. A. Pfeiffer, R. Buxton, J. Gardiner, W. Liu, R. F. Hunter and M. P. White (2021). "Contact With Nature as a Mental Health Buffer for Lower Income Communities During the COVID-19 Pandemic." Frontiers in Sustainable Cities **3**(86). https://www.frontiersin.org/article/10.3389/frsc.2021.688473

57. DeVille, N. V., L. P. Tomasso, O. P. Stoddard, G. E. Wilt, **T. H. Horton**, K. L. Wolf, E. Brymer, P. H. Kahn, Jr. and P. James (2021). "Time Spent in Nature Is Associated with Increased Pro-Environmental Attitudes and Behaviors." Int J Environ Res Public Health **18**(14). https://www.ncbi.nlm.nih.gov/pubmed/34299948

56. Pearson, A. L., K. A. Clevenger, **T. H. Horton**, J. C. Gardiner, V. Asana, B. V. Dougherty and K. A. Pfeiffer (2021). "Feelings of safety during daytime walking: associations with mental health, physical activity and cardiometabolic health in high vacancy, low-income neighborhoods in Detroit, Michigan." International Journal of Health Geographics **20**(1): 19. https://www.ncbi.nlm.nih.gov/pubmed/33941196

55. Beller Stryer, S., C. Schultz and **T. H. Horton** (2020). "Creating Healthier School Communities Through Nature." School Business Affairs. **November 2020**: 12-15. asbointl.org

54. **Horton, T.H.** (2020). We need nature and recreation during the COVID-19 pandemic. National Recreation Foundation Blog. March 28, 2020 https://www.nationalrecreationfoundation.org/blog/we-need-nature-and-recreation-during-the-covid-19-pandemic/

53. **Horton, T.H**. and S. Bartlett-Hackenmiller. (2020). Commentary: Take a hike! Getting outside will help us through this pandemic. Chicago Tribune, March 20, 2020. https://www.chicagotribune.com/opinion/commentary/ct-opinion-coronavirus-anxiety-outdoors-walks-20200320-ehpmdqwu75eqbicrs4mvtazyce-story.html

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Appendix 2. Most recent publication by Teresa H. Horton (Document pages 142-160)

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

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Abstract

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

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

Introduction

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

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

Nature health benefits

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

Nature-based components

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

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

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

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

Table 1. Glossary of Key Terms

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

Role of public health

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

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

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

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

Methods

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

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

Results

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

Amount and location of nature-based components and PA

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

Children and Adolescents

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

Adults

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

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

Older Adults

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

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

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

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

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

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

Physiological

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

Psychological/Emotional

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

Cognitive Function and Experience

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

Social Relationships

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

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

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

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

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

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

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

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

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

Environmental Justice

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

Non-White, Marginalized, and Vulnerable Populations

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

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

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

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

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

Discussion

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

Gaps in knowledge

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

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

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

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

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

Improving Access to Nature for All Populations

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

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

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

Education on Nature and Nature-Based PA

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

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

Increased Access to Community Nature-Based Components

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

Improving Safe Active Transportation

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

Conclusion

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

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