

Imagining Eco-Wellness: A Scoping Review of Interventions Aimed at Changing Individual Behaviors to Promote Personal Health and Environmental Sustainability

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ABSTRACT

Introduction: Climate change poses enormous threats to humanity and much of life on earth. Many of the behavioral patterns that drive climate change also contribute to the epidemics of obesity, diabetes, and cardiovascular disease.

Objectives: The primary objective of this study was to compile and categorize the literature on interventions aimed at modifying individual behaviors to promote both personal health and environmental sustainability. Secondary objectives were to help define the emerging field of behavioral eco-wellness and to discuss future directions, including the need for assessment tools and analytic strategies.

Methods: A scoping review was conducted to locate, categorize, and interpret current scientific studies of interventions aimed at changing individual behaviors to promote both personal health and environmental sustainability.

Results: Other than a pilot study that this team previously conducted, nothing was found that strictly fit the inclusion criteria. However, we did find 16 relevant studies that fit neatly within 4 broad topical areas: active transportation, dietary intake, indoor air quality, and green space immersion.

Discussion: While this systematic scoping review found little meeting original criteria, we did find that 4 separate fields of study are converging on a scientific area that we are calling behavioral eco-wellness, defined as the simultaneous pursuit of both personal health and environmental sustainability. The emerging field could provide a conceptual framework and methodological toolkit for those seeking to enhance sustainability while supporting health behaviors, including dietary intake. This, in turn, could help to inform and motivate the urgent action needed to confront both climate change and the epidemics of obesity, diabetes, and cardiovascular disease.

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INTRODUCTION

Agencies, governments, organizations, and experts across the world have highlighted the potential devastation of climate instability and the urgency of actions needed.¹ Many individuals and groups are engaged in researching policies, technologies, and interventions to reduce greenhouse gas emissions to mitigate the magnitude of and destructive effects of climate change. Most climate action recommendations are rooted in science from studies analyzing the large-scale impact of technologies, policies, or lifestyle changes. However, little is known about interventions designed to help individuals modify their behaviors to reduce their carbon footprint.

While the climate crisis has been declared the largest single threat to global health in the foreseeable future,²⁻⁴ the epidemics of obesity, diabetes, metabolic syndrome, and cardiovascular disease also are jeopardizing the health of countless people across the globe. A number of authors have noted that many of the same behaviors that reduce carbon footprint also help

ameliorate these disease burdens.⁵⁻⁷ For example, walking, running, or bicycling rather than driving an automobile provide “co-benefits” of better health and a lower carbon footprint.⁸⁻¹⁰ Similarly, replacing meat and dairy with plant-derived foods, such as whole grains, nuts, legumes, and vegetables, will lead to both a lowered carbon footprint and improved health.¹¹⁻¹³ Moreover, it is possible that health and sustainability motivations may be mutually reinforcing. Individuals may be more apt to consider taking

action for our climate when educated on the positive health benefits of said actions.¹⁴ Or, knowing that they will be contributing to sustainability, people may be more likely to adopt recommended health practices.¹⁵ Interventions aimed at eco-wellness, defined as the simultaneous pursuit of both personal health and environmental sustainability, may be more effective than those aimed at only one of these targets.

The concept of eco-wellness is particularly apt for the field of nutrition. Because of positive effects for both physiological health and environmental sustainability, the reduction of meat and dairy in the diet has been widely discussed in the literature.^{7,11,12,16-18} It is well known that animal-based foods disproportionately contribute to land and water use, air and water pollution, and carbon footprint. Globally, at least 26% and perhaps as much as 35% of anthropogenic greenhouse gases come from food production.^{19,20} A recent comprehensive life cycle analysis found that worldwide meat production leads to twice the total greenhouse gas emissions as plant foods, despite the fact that meat represents less than 10% of global calories.¹⁹ One systematic review found that for some affluent areas, reduction in greenhouse gas emissions of 50% or more could be achieved by dietary changes alone.²¹

At the same time, due to high calories and unfavorable fat profiles, animal-based foods are contributors to the global epidemics of obesity, dyslipidemia, and cardiovascular disease, substantively contributing to morbidity and mortality.^{22,23} Supporting this conclusion, recent studies have found linear dose-response relationships between red meat consumption and premature death, with an estimated 10% increase in mortality associated with an increase of 100 g of daily meat consumption.²⁴⁻²⁶ Nevertheless, despite the well-known health and environmental benefits of transitioning away from meat and dairy and towards a plant-based diet, very few interventions have been developed and tested towards these ends.

Over the past few years, our team developed and piloted the Mindful Climate Action behavioral change program, a mindfulness-based approach aimed at the simultaneous pursuit of both personal health and environmental sustainability.²⁷⁻²⁹ Outcomes assessed in our pilot studies include miles and minutes spent walking, bicycling, and driving; household consumption of gas, electricity, and water; and proportion of diet from animal-based versus plant-based sources, assessed using the Automated Self-Administered 24-hour Dietary Assessment Tool (ASA24). Our team also developed a new dietary intake environmental impact calculator to help support this work. The Multi-factor Dietary Impact on the Environment Tool (miDIET) takes self-report data from the ASA24 and then applies environmental impact factors to produce individual-level sustainability metrics, including carbon footprint.³⁰ This pilot work also included data from validated self-report instruments assessing mental and physical health, self-efficacy, perceived stress, depressive symptoms, presenteeism at work, and happiness.

Experience with this previous work prompted us to look for other studies examining interventions aimed at influencing eco-wellness behaviors. The basis of our definition of intervention was influenced by the National Institutes of Health definition. We sought to find prospective studies involving the manipulation of a human subject's environment to evaluate the effect of the intervention on the study participants' health (either health-related biomedical or behavioral outcome) and on some form of sustainability. Examples of strategies to change health and sustainability-related behaviors include cognitive therapy, motivational interviewing, diet, exercise, or development of new habits.³¹

An initial literature search found no previously published systematic or scoping reviews of individual-level interventions aimed at behavioral eco-wellness. Therefore, our group launched such a review, reported here.

The primary objective of this study was to compile and categorize the literature on interventions aimed at modifying individual behaviors to promote both personal health and environmental sustainability. Secondary objectives were to help define the emerging field of behavioral eco-wellness and to discuss future directions, including the need for fit-for-purpose methods, including assessment tools and analytic strategies for evaluating the efficacy and effectiveness of these interventions for both individual and environmental health.

METHODS

To meet the primary objective, we first sought published empirical studies that: (1) conducted an intervention aimed at changing behaviors, (2) were delivered at the individual or group level, with pre- and post-intervention assessments including (3) at least 1 measure assessing a mental or physical health attribute, and (4) at least 1 measure directly related to environmental sustainability (eg, reduced waste, energy use, or carbon footprint; improvement of air or water quality). Our search strategy was limited to English language publications that included terminology regarding both sustainability (environment, climate) AND health (physical, mental, well-being, health behavior). We relied heavily on the term “co-benefit,” as this encompasses the intersection of human health and the environment. See supplemental material for specific search terms and strategy.

The scoping review process was guided by the PRISMA Scoping Review guidelines³² and is summarized in the Figure. The search strategy was developed with health sciences academic librarians, including coauthor MH. We used 3 databases—PubMed, Agricultural and Environmental Science Collection, and Scopus—aiming to identify articles that fulfilled our search criteria. There were no publication date restrictions. The original search was completed by MH on March 6, 2020, then repeated on July 27. The final search was done on January 15, 2021, with the condition that the publication date was limited to the year 2020.

Results were compiled, and duplicate items were removed

using Endnote X9, resulting in 572 article titles from the original search, a number that increased to 721 titles after the January 2021 search was completed (see Figure). Team members SR and SW screened all titles for inclusion criteria, resulting in a total of 476 abstracts being reviewed (431 abstracts from the original search). Abstracts were read initially by team members SR and SW, who selected 111 abstracts for indepth review by the full team. The titles and abstracts rejected at the first 2 stages did not describe empirical studies of small group or individual-level interventions aimed at behavior change. The 111 resulting abstracts were read by team members BB, BK, and SW, applying the entire set of inclusion criteria. In case of discrepancy, team member MG reviewed the abstract. Group consensus was achieved by discussion. Database searches resulted in 17

publications that were read in full by at least 2 team members. To complement the online database search, senior author BB sent email queries to 41 published experts asking for studies that matched our inclusion criteria. The list of experts queried was based on having published relevant literature. This resulted in 12 additional abstracts, which were then reviewed by at least 2 team members (BB, BK, and/or SW), resulting in 6 publications recommended by experts being read in full.

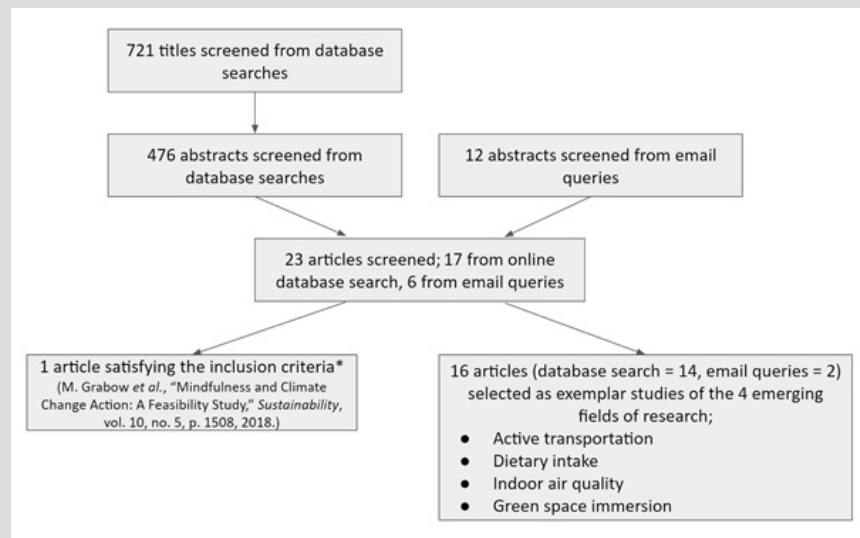
These 2 search processes resulted in 23 papers (17 from the first online database search, none from the second and third online database search, and 6 from authors contacted by email), which were read in full by at least 2 team members (BB, BK, MG, and/or SW) and analyzed for eligibility based on the inclusion criteria described above.

RESULTS

After full-text reviews, we found no studies that strictly fit the inclusion criteria, with the exception of our own Mindful Climate Action pilot study.²⁷ Reasons for exclusion varied. Many papers were based on theory or models and did not include empirical outcome data from a prospective study design. A number of papers did not include at least 1 health and 1 sustainability outcome measure. Some did not describe discrete interventions, and some were not aimed at addressing individual behaviors. Other than our own work, not a single paper described an empirical study describing an intervention aimed at changing individual behaviors to impact health and sustainability co-benefits.

Nevertheless, despite this null finding, we did identify 4 broad categories of literature relevant to the goal of assessing and influ-

Figure. Flow Diagram Showing Review Strategy



*Inclusion criteria were empiric studies that: (1) conducted an intervention aimed at changing behaviors, (2) were delivered at the individual or group level, followed by post-intervention assessments including (3) at least 1 measure assessing a mental or physical health attribute, and (4) at least 1 measure directly related to environmental sustainability.

encing both personal health and environmental sustainability: (1) dietary intake, (2) active transportation, (3) indoor air quality, and (4) green space immersion. The emergence of these 4 categories occurred after reading the 23 papers but was strongly informed by reviewing the 721 titles and 476 abstracts. Of the 23 papers, 16 fit within these categories and serve here as exemplars of the potential of behavioral eco-wellness as a burgeoning field. (See Tables 1-4.) The 16 papers included 3 papers involving dietary change, 3 papers focusing on active transportation, 7 papers investigating indoor air quality, and 3 papers looking at green space immersion. All of these were published after 2010. Thirteen of the 16 studies were published after 2015. While this paper highlights research on dietary intake for health and sustainability co-benefits, we also summarize what we found in the other 3 areas.

Dietary Intake

This scoping review did not find any reports of empirical testing of behavioral interventions aimed at changing individual diets to achieve both health and environmental benefits. However, we did discover an emerging stream of literature pointing in this direction. There were large-scale analyses of potential co-benefits of dietary change.^{11,21} There were several regional studies looking at health and sustainability correlates of dietary intake patterns.³³⁻³⁵ There were discussions and analyses of how people might be persuaded to modify their diets towards health and sustainability.^{16,36,37} Nevertheless, as far we could find, there were no empirical studies testing interventions aimed at changing dietary intake that included outcome measures relating to both personal health and environmental sustainability.

Table 1. Dietary Intake: Analysis of Major Criteria and Sample Size of Final Review Studies Within the Dietary Intake Category

Studies	Presence of Inclusion Criteria	Study Design	Population	Sample Size	Type of Intervention	Mental/Physical Health Outcome	Environmental Sustainability Outcome
Aston et al, 2012 ³⁸	C, D	Modelling	British general public	N _i =1724	None (consumption of red and processed meat)	Risk of coronary heart disease, diabetes, colorectal cancer	Greenhouse gas emissions from dietary intake
Behrens et al, 2017 ³⁹	D	Modelling	NA	NA	None (Nation-specific nationally recommended diets)	None	Impact of diets on greenhouse gases, eutrophication, land use
Bharucha et al, 2020 ⁴⁰	C	Cross-sectional study	Participants of local food initiatives in the United Kingdom	Local food initiatives (N _i =302), general population (N _i =157)	None (local food project participants)	Psychological need satisfaction, diet, nature-connectedness, physical activity	None

Inclusion criteria were empiric studies that: (A) conducted an intervention aimed at changing behaviors, (B) were delivered at the individual or small group level, followed by post-intervention assessments including (C) at least 1 measure assessing a mental or physical health attribute, and (D) at least 1 measure directly related to environmental sustainability.

N_i indicates the number of individual participants.

Table 2. Active Transportation: Analysis of Major Criteria and Sample Size of Final Review Studies Within the Active Transportation Category

Studies	Presence of Inclusion Criteria	Study Design	Population	Sample Size	Type of Intervention	Mental/Physical Health Outcome	Environmental Sustainability Outcome
Chapman et al, 2018 ⁴³	A, C, D	Prospective cohort	Community households in 4 New Zealand cities	Interventional (N _H =1120) control (N _H =1020)	Incorporation of walking, cycling programs	Disability adjusted life years	Transport-related carbon emissions
Frank et al, 2010 ⁴⁵	C, D	Cross-sectional study	Participants >16 years old in Atlanta, Georgia region	N _i =10,148	None (Built environment's impact on transportation)	Kilocalories burned from walking	Kilocalories burned from motorized transport (ie, CO ₂ emissions)
Keall et al, 2015 ⁴⁴	A	Prospective cohort	Community households in New Zealand cities	Interventional (N _H =1120), control (N _H =1020)	Incorporation of walking and cycling programs	Rates of active travel ^a	Rates of active travel ^a

Inclusion criteria were empiric studies that: (A) conducted an intervention aimed at changing behaviors, (B) were delivered at the individual or small group level, followed by post-intervention assessments including (C) at least 1 measure assessing a mental or physical health attribute, and (D) at least 1 measure directly related to environmental sustainability.

N_H indicates the number of households, and N_i indicates the number of individual participants.

^aIndicates outcome measurement not adequate to meet inclusion criteria.

The 3 studies that we chose to include as exemplars are shown in Table 1.³⁸⁻⁴⁰ Two of these utilized a modeling method, while the third conducted a cross-sectional study. Two papers studied populations in the United Kingdom, while the other looked at diets from a global perspective. Studies variously focused on reduced meat consumption, the environmental impact of nationally recommended diets, and the impact of local food initiatives. Two studies estimated greenhouse gas emissions as an environmental outcome, with one also including eutrophication and land use. One study measured health outcomes (coronary artery

disease, diabetes, and colorectal cancer), and another assessed psychological need satisfaction, fruit and vegetable intake, nature connectedness, and physical activity.

Active Transportation

Modifying transportation infrastructure and supporting active transportation has been discussed at length in the literature as a major potential source of health and sustainability co-benefits.^{6,41,42} Nevertheless, very few empirical studies aimed at supporting active transportation have been conducted. The majority of the papers we found described modeling studies. Here we will

Table 3. Indoor Air Quality Analysis of Major Criteria and Sample Size of Final Review Studies Within the Indoor Air Quality Category

Studies	Presence of Inclusion Criteria	Study Design	Population	Sample Size	Type of Intervention	Mental/Physical Health Outcome	Environmental Sustainability Outcome
Anderman et al, 2015 ⁴⁹	C	Cohort	Households in southern India	N _H =199	None (Biogas cook stove vs traditional stove)	Dietary diversity	Subjective firewood utilization ^a
Aung et al, 2018 ⁵⁰	A, B, C	Randomized control trial	Women >25 years in India	Control N _I =111 and intervention N _I =111	Rocket cook stove vs traditional stove	Systolic/diastolic blood pressure, self-reported eye symptoms	Fine particle (PM 2.5) mass and absorbance around cooking area ^a
Barn et al, 2018 ⁵⁴	A, B, C	Randomized control trial	Nonsmoking pregnant women in Mongolia	Control N _I =253 and intervention N _I =259	HEPA filter air cleaners vs no air cleaners	Blood cadmium and hair nicotine from second-hand smoke exposure	Indoor and outdoor PM 2.5 ^a
Champion and Grieshop, 2019 ⁵¹	A, B, C	Cohort	Households in Rwanda	Pellet stove (N _H =14), (N _H =4), and charcoal stove (N _H =4)	Pellet cook stove vs wood/charcoal wood stove	Carbon monoxide exposure stoves	Estimated tons of CO ₂ equivalent per year of cookstove use and indoor PM 2.5 ^a
Patange et al, 2015 ⁵²	C	Cross-sectional study	Households in India	Forced draft stove N _H =10 stove N _H =12	None (forced-draft cook stove vs and traditional)	Black carbon exposure (traditional stove)	Black carbon around cooking area ^a
Wathore et al, 2017 ⁵³	C	Cross-sectional study	Households in Malawi	Households N _H =22	None (Alternative cookstoves [ceramic forced-draft, institutional models] vs traditional cookstoves)	Carbon monoxide exposure	Indoor PM 2.5 ^a
Zhou et al, 2014 ⁵⁵	A, B, C	Cohort	Participants >40 years in southern China	N _I =996	Household biogas digester for clean fuel usage and kitchen ventilation	FEV1 and risk of COPD	Indoor SO ₂ , CO, CO ₂ , NO ₂ , and PM <10

Abbreviations: PM, particulate matter; FEV1, forced expiratory volume in 1 second; COPD, chronic obstructive pulmonary disease; SO₂, sulfur dioxide; CO₂, carbon dioxide; CO, carbon monoxide; NO₂, nitrogen dioxide.

Inclusion criteria were empirical studies that: (A) conducted an intervention aimed at changing behaviors, (B) were delivered at the individual or small group level, followed by post-intervention assessments including (C) at least 1 measure assessing a mental or physical health attribute, and (D) at least 1 measure directly related to environmental sustainability.

N_H indicates the number of households, and N_I indicates the number of individual participants.

^aIndicates outcome measurement not adequate to meet inclusion criteria.

mention 3 empirical studies, 2 studies using a prospective cohort design in New Zealand, and the other using a cross-sectional design in the United States (Table 2).⁴³⁻⁴⁵ All of these studies looked at the impacts of the built environment and socioeconomic factors on active transportation. The environmental outcome measurement was related to motorized vehicle emissions in 2 of the 3 studies. The health outcomes measure varied, including disability-adjusted life years in one study and kilocalories burned during active transportation in another. One of the studies looked generally at rates of active travel and the likely impact on health and environmental outcomes.

Indoor Air Quality

Our scoping review yielded dozens of studies assessing the use of new or upgraded cook stoves and other technological approaches

to improve indoor air quality. This is unsurprising given the well-known effects of air pollution—especially fine particulates—on human health.⁴⁶⁻⁴⁸ Nevertheless, while some studies assessed both health and environmental outcomes, none of these were aimed at changing individual behaviors. Of the 7 exemplar studies, 3 studies used randomized controlled trial methods, 2 studies utilized a cross-sectional design, and 2 studies used a prospective cohort design (Table 3).⁴⁹⁻⁵⁵ Five studies were conducted in Asia (3 in India, 1 in Mongolia, 1 in China), and 2 studies were conducted in Africa (Rwanda and Malawi). Six studies investigated “cleaner” cooking stoves, and 1 study researched HEPA air filters. Four studies measured indoor fine particulate matter (PM_{2.5}) as an environmental outcome. Other studies measured black carbon concentration, fuel use, and other indoor air pollutants, includ-

Table 4. Green Space Immersion: Analysis of Major Criteria and Sample Size of Final Review Studies Within the Green Space Immersion Category

Studies	Presence of Inclusion Criteria	Study Design	Population	Sample Size	Type of Intervention	Mental/Physical Health Outcome	Environmental Sustainability Outcome
Coventry et al, 2019 ⁶¹	C, D	Cross-sectional study	Conservation volunteers in the UK	N _i =45	None (guided walks, practical conservation or citizen science in urban or semi-urban green spaced)	Mood and stress	Engagement in conservation and sustainable urban development
Raymond et al, 2019 ⁶²	C, D	Semistructured qualitative interviews	Home gardeners in Winnipeg, Canada	N _i =50	None (gardening for biodiversity)	Subjective psychological, physiological, cognitive, and social benefits	Subjective environmental benefits of conservation of native habitat
Reeves et al, 2019 ⁶³	B, C	Self-controlled case series	Healthy participants in London, England	N _i =36	Exposure to urban green spaces	EEG measurements and self-reported stress, anxiety, depression	None

Abbreviations: EEG, electroencephalogram.

Inclusion criteria were empiric studies that: (A) conducted an intervention aimed at changing behaviors, (B) were delivered at the individual or small group level, followed by post-intervention assessments including (C) at least 1 measure assessing a mental or physical health attribute, and (D) at least 1 measure directly related to environmental sustainability.

N_i indicates the number of individual participants.

^aIndicates outcome measurement not adequate to meet inclusion criteria.

ing CO₂. The studies investigated health outcomes, including blood pressure, eye symptoms, cardiopulmonary and cardiovascular disease mortality, hair nicotine and blood cadmium levels, lung function, incidence of chronic obstructive pulmonary disease, and carbon monoxide exposure. One nonrandomized study from India (n = 199 households) found that households using clean biogas cook stoves reported greater dietary diversity than comparison households.³⁶

Green Space Immersion

Experiencing nature (ie, green space immersion, forest bathing, shinrin-yoku, nature immersion, etc) has emerged as a potential avenue toward better mental and physical health and also as a way to foster ecological values.⁵⁶⁻⁶⁰ Included here as 3 exemplars, 2 green space immersion studies implemented a qualitative approach, while a third study utilized a cross-sectional design (Table 4).⁶¹⁻⁶³ The studies included short-term exposure to urban green spaces, guided walks/practical conservation tasks/citizen science in urban and semi-urban green spaces, and home gardening for biodiversity. All 3 studies assessed general indicators of physical and psychosocial wellness; one also included measures of stress response, self-reported mood, and heart rate. We did not find green space immersion studies that specifically looked at potential relationships with food production or dietary intake.

DISCUSSION

Although we found no investigations other than our pilot study that matched the specific inclusion criteria, we did find emerging literatures regarding 2 sets of eco-wellness behaviors with well-

known health and sustainability co-benefits (active transportation and food choice), as well as research in 2 areas where co-benefits from behavior change have received less attention (indoor air quality and green space immersion). The findings of this scoping review provided new insights into the emerging field we call “behavioral eco-wellness,” with 4 streams of literature converging on a new transdisciplinary science concerned with both personal health and environmental sustainability. The exemplar studies in Tables 1-4 highlight the 4 areas and attest to the rapidly rising importance of this emerging field, with the majority of studies published within the last 5 years.

To our knowledge, no previous reviews have attempted to systematically locate and contextualize published studies of interventions aimed at influencing individual behaviors that impact both personal health and environmental sustainability. While our research team uses the term “eco-wellness” to describe this emerging field, it should be noted that the word “ecowellness” has been used previously by Reese et al, who described it as “a sense of appreciation, respect for, and awe of nature that results in feelings of connectedness with the natural environment and the enhancement of holistic wellness.”⁶⁴⁻⁶⁶ We consider Reese’s work to be very much in line with the literature on green space immersion that we identified. We build on Reese’s ecowellness work by looking more broadly at scientific studies of behaviors and interventions that influence both human health and environmental sustainability rather than only those aimed at the health benefits of experiencing nature.

The emergent field of eco-wellness research seeks to investigate

pathways influencing both sustainability and health. Defining the field of behavioral eco-wellness as the study of how individual behaviors impact personal health and environmental sustainability will allow for a wide variety of research topics to be brought together into a unified yet multidisciplinary field of research, in order to contribute substantively towards both climate change mitigation and the epidemics of obesity, diabetes, and cardiovascular disease. Reaching towards these goals will require new conceptual structures, as well as new assessment tools. Development and validation of new tools for measuring eco-wellness outcomes should be guided by theory and supported by both hypothesis-testing and conceptual restructuring and synthesis.

We would be remiss to not mention the importance of equity embedded within the topic of behavioral eco-wellness. Our search criteria were already so specific in nature by combining health and sustainability that adding a health equity component might have rendered us incapable of producing any useful results. As the field of eco-wellness develops and co-benefit strategies evolve, diversity, equity, and inclusion must remain a top priority. In fact, our colleagues at the University of Wisconsin–Madison recently published a scoping review of active transportation interventions and their effects on health equity, finding that significant gaps exist in our understanding of how health inequities could be mitigated through modifying the active transportation environment because it is understudied and undervalued.⁶⁷

To expand the field of behavioral eco-wellness, measurement of personal health and environmental sustainability outcomes should become more accessible, standardized, precise, reliable, and easy-to-implement in diverse study designs. For example, improved measurement of physical activities, such as active transportation, will be needed and will likely include global positioning system (GPS)-enabled smartphone applications and other wearable technologies. Our research group has used Moves, Move X, and Arc, which are smartphone apps that map personal movement on streets, walking paths, and bike lanes, yielding estimates of minutes and miles of walking, bicycling, and driving that, in turn, can be used by the researchers to estimate both carbon footprint and personal health benefits.^{27,28} These movement-measuring tools were developed to assess personal movement metrics but do not assess other eco-wellness behaviors, such as using stairs rather than elevators or choosing to drive an electric car, a fossil-fueled vehicle, a hybrid car or use public transportation.⁶⁸ Currently available tools for estimating the carbon footprint of an individual's transportation behaviors require make, model, and year of vehicle; an assessment of "miles driven;" and application of weighting factors, a process that is effort-intensive. Computer programs and smartphone-based apps to reduce the effort should be developed and tested. Better methods for assessing the health and environmental impacts of public transport also are needed. The creation of a comprehensive smartphone application or wearable technology that accurately tracks active and fossil-fueled

transportation with the ability to internally calculate the carbon footprint of an individual's movement could improve the accuracy and accessibility of eco-wellness research.

There are currently no properly validated systems to assess dietary intake for both health and sustainability outcome assessment. Various diet measurement tools, such as food frequency questionnaires, 24-hour recalls, and prospective logs, can estimate dietary intake but are known to be inaccurate as well as time-consuming.⁶⁹ A goal of dietary eco-wellness assessment is to identify the quantity of specific foods ingested, then link that information to data from studies looking at health outcomes and sustainability impacts of those foods in terms of carbon footprint.³⁰ Future directions may include mobile technologies and computerized analysis of photos of meals taken by research participants on their smartphones, such as the Technology Assisted Dietary Assessment (TADA) system developed by researchers at Purdue University.⁷⁰⁻⁷² Researchers in Australia are adapting the TADA system with the aim of measuring both the health and sustainability impacts of individual diets.⁷³ As another example, smartphone applications have been used in Denmark grocery outlets in an attempt to provide nutritional and environmental information to supermarket shoppers.⁷⁴ While some nutritional information is typically available for many foods, assessment and labeling of different foods' carbon footprints and other environmental impacts will need to be improved for the advancement of eco-wellness research related to food production and consumption.

Although several indoor air quality studies were found in this scoping review, there is an inherent difficulty in measuring sustainability outcomes of improved cook stoves and other air quality technologies. We also know this has links to nutrition as cooking and cooking methods may also affect the nutritional content and nutrient availability of food. Understanding the interplay between the energy we use for cooking and its impact on sustainability metrics is a complicated process. Creating a standardized formula to determine the environmental impacts of cook stoves could propel this area of research forward in the field of eco-wellness. Modeling of clean cook stove interventions does show promise of widespread health and environmental benefits, specifically in low- and middle-income countries.⁷⁵ But many indoor air pollution projects fail to address how individuals would realistically utilize these interventions.⁷⁶ To advance in this field, improving the design of the interventions and their implementation will be necessary to utilize funding effectively and to improve stakeholder livelihood.^{77,78} Assessment of the interactions between new stove use, food choice, and nutritional intake also will be needed. If indoor air quality research does not address realistic practicality in study design and sustainability measurement tools, the adaptation within the eco-wellness framework will continue to be limited.

In addition to improving the toolkits available for measuring the co-benefits of active transportation and dietary intake, better methods are needed to assess potential health and sustainability

outcomes attributable to experiencing the natural environment. During the past few years, a growing body of literature has begun to describe health benefits from spending time in nature.⁷⁹⁻⁸¹ Nevertheless, studies to date are almost entirely observational rather than experimental, with interventions and outcomes either poorly described or not yet validated. A few studies in this emergent scientific area have attempted to assess health outcomes, but little attention has been paid to the potential feedback loop toward improvement of environmental preservation and sustainability behaviors. Quite plausibly, nature immersion could lead to improved personal sustainability behaviors and improved health, or even perhaps environmental advocacy or sustainability-directed political activism. Undoubtedly, there is also potential overlap with the domains of active transportation and nature immersion as well as mindful eating and nature immersion, as experiencing nature may change how one is motivated to move and eat more in accordance with sustainability principles. However, without proper testing, such potential co-benefits remain hypothetical rather than empirically tested.

Improvements in study design will be essential in furthering the field of eco-wellness. Many studies found in this field utilize observational methods without any sort of intervention or pre-/post-assessment. This likely is due to multiple reasons, notably the financial feasibility of conducting an intervention, assessing control conditions, and completing baseline and follow-up assessments. Modeling studies are quite popular, especially in the active transportation area of research. These methods allow researchers to illuminate the potential impact of large-scale interventions but do not empirically assess intervention effects. This review found several studies employing observational data and modelling methods but almost no experimental studies assessing the results of interventions. Considering the rapid progression of climate instability and the increasing obesity epidemic worldwide, we conclude that there is an urgent need to develop and test promising behavioral interventions. Moving toward experimental study design methods will be essential for eco-wellness research to take the next steps towards rigorous and generalizable information that can be used to improve human health and environmental sustainability.

We were impressed by the fact that the 4 identified domains not only overlapped but were characterized by potential interactions and perhaps synergy. For example, while we selected Bharucha et al as a dietary study exemplar, that paper also discussed the psychological benefits of interacting with local green spaces and initiatives and so could have instead been categorized under green space immersion.³⁹ Similarly, many of the indoor air quality studies were based on the development and testing of cook stoves, which has obvious yet largely unexplored implications for healthy and sustainable dietary intake. Less obvious but nonetheless important may be the impacts on active transportation; procurement of fuel and foodstuffs requires movement and trans-

portation, which is likely to be influenced by type of stove, fuel, and cookware used. Another example would be the interactions between transport, green space, and types of food consumed. In both urban and rural communities, choice of foodstuff and considerations such as packaging and shelf life may affect whether walking or bicycling are possible or whether fossil-fueled transportation is needed. Food delivery systems might affect people's physical activity patterns. Developing and protecting greenspace might influence personal transportation choices, both related and unrelated to dietary intake. While fully comprehensive studies may not be possible, the incipient field of behavioral eco-wellness should strive to be holistic and comprehensive enough to take into account as many relevant outcome domains as possible, so as to maximize useful knowledge and perhaps avoid undesirable unintended consequences.

These considerations further highlight the importance of defining search terms, keywords, sub-fields, and domains of study for the field of behavioral eco-wellness to move forward. We used the term co-benefit as part of our search criteria, which may have limited the extent of our findings since it may not be an umbrella term used worldwide. While we did include expert inquiries to help identify potential blind spots in our scoping review's methodology, it is likely that individual studies or even whole fields of relevant research may have slipped past our review. As with all systematic or scoping reviews, papers published in journals not encompassed by the search strategy (nonindexed journals, gray literature) likely will have been missed. With the understanding that the study of eco-wellness is only now emerging (the majority of our exemplars were conducted in the last 5 years), this scoping review does not claim to have exhaustively found all studies in the 4 research domains identified and does not assert that the study of eco-wellness is limited to these 4 areas. It is possible that we missed a study that would have met our strict inclusion criteria. However, even if that were the case, we do not believe that would substantively change our findings, conclusions, or interpretation. In the future, it will be important for research within the field of eco-wellness to be published using consistent terms and for scientists to communicate and work together to consolidate and develop this field.

Given the enormous challenges posed by climate change and the epidemics of obesity, diabetes, and cardiovascular disease, it is incumbent upon us to grow and strengthen these areas of research as swiftly and comprehensively as possible.

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