ORIGINAL ARTICLE

Green buildings and their impact on health outcomes and dietary intake: What do we know?

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ABSTRACT

Background: While numerous research has been conducted on the energy efficiency advantages of green buildings, there remains a limited exploration of their effects on individuals' health conditions and dietary intake. Green building's structure and design aim to reduce the impact on the surrounding environments while also helping to improve the quality of health of individuals who live within them.
Aim: The objective of this study was to examine the impact of green buildings on health outcomes and dietary intake.
Method: Using four databases (Agricola, EBSCO, PubMed, and Web of Science), search of literature was directed with the following keywords: green buildings, green homes, built environment, housing design, health outcomes, dietary patterns, dietary intake, eating behavior, food choices, and others. We reviewed 33 articles, and 19 met our inclusion criteria.
Results: The synthesis of literature revealed four overarching themes: the association between green buildings and respiratory diseases, mental health, dietary intake, and physical activity level. Our findings suggest an association between green buildings and the improvement of certain health conditions, including asthma, depression, and obesity.
Conclusion: The results emphasize the necessity for additional research to investigate the sustained impact of green buildings on residents' health and dietary habits over an extended period. The implications of the findings are significant for policymakers, urban planners, and researchers, underscoring the potential of green building initiatives in promoting healthy living environments.

Key Words: Green buildings, Built environment, Dietary patterns, Obesity, Asthma, Mental health

1. INTRODUCTION

Green buildings aim to improve the health of their occupants by utilizing healthy indoor environment and improving indoor design. Similar to green buildings, green homes employ the same principles to reduce the impact on the surrounding environments while also helping to improve the quality of life of individuals who live within them. One way is by influencing an individual's lifestyle directly through the design of the building or another by influencing indirect effects on health through utilizing resources and implementing measures that reduce environmental pollution.[1] The reductions to environmental pollution are achieved by curtailment of energy and water usage, improving air quality, and reducing any environmental disruption to the site where the building resides.[1]

While considerable research has investigated the energy efficiency benefits of Leadership in Energy and Environmental Design (LEED) certified buildings,[2] there is a dearth of studies exploring the effects of green and LEED-certified structures on individual health outcomes and dietary intakes.

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This study aims to fill this gap by examining the influence of green buildings on the health outcomes and dietary intake of individuals. Dietary intake or pattern is the combination of food and beverages that constitutes an individual's complete eating consumption over time.[3,4] Along with physical inactivity, insufficient sleep, and smoking, unhealthy dietary intakes are associated with higher risk of chronic diseases and obesity among individuals.[3–6] In the United States, obesity among adults was prevalent at 41.9%, and the prevalence of severe obesity increased from 4.7% to 9.2% between 2017 and 2020.[4] Furthermore, chronic diseases are the leading causes of death and disability in the United States and in every ten adults at list six have a chronic disease.[4,5] Healthcare expenses of chronic disease alone costs the United States about four trillion annually.[5] This study seeks to contribute to the understanding of how green building environments may contribute to improved health outcomes and reduced risk factors for chronic diseases.

2. METHOD

Search of peer-reviewed literature published between January 2011 and December 2022 was conducted using the following four databases: Agricola, EBSCO, PubMed, and Web of Science.[7–10] The search looked for specific keywords including green spaces, green buildings, green homes, built environment, green renovations, housing design, socioeconomic change, health outcomes, health impacts, dietary patterns, dietary intake, dietary behaviors, eating behavior, food choices, food patterns, and food environment. Other articles were also identified based on review of chosen articles and their references.

We also used LEED certification as a keyword to identify literature related to green building in our search.[2] LEED certification includes specific standards that a building needs to comply with in order to address environmental concerns.[11] Using each standard to gain eligibility as a way to factor in all the vital elements needed to support the best types of buildings that protect the environment and its people.[11] The LEED rating system has been used on any type of buildings making it relatively valuable when designing a building that supports the environment and green spaces.[11,12]

We employed scoping review methodology to comprehensively survey the literature and categorize it into common themes. Scoping review methodology involves a systematic and iterative process for mapping out existing literature on a particular topic, providing a comprehensive overview of the field.[13,14] Articles were selected from the database search and independently reviewed by two researchers against the following inclusion criteria: (1) publication in English, (2) article published in a peer-reviewed journal, (3) research method directly measured building structure or design, and (4) inclusion of research variables or findings related to changes in health outcomes or dietary behaviors. Relevant literature was then categorized into themes based on correlation in variables or outcomes and grouped accordingly. Irrelevant data and duplicate findings were excluded. Thematic analysis was utilized to illuminate key aspects of health conditions and outcomes linked to green buildings, thereby establishing a framework of codes to ensure compliance with green building standards. Within this analytical framework, overarching themes emerged, presenting various aspects of the relationship between green buildings and health outcomes, as well as dietary intake. These themes were delineated based on evidence convergence from included studies, with each theme comprising specific studies for comprehensive exploration.

3. RESULTS

A total of 33 articles were identified among which 19 articles met the inclusion criteria and were included in this study. Articles included studies that were conducted in a variety of countries and utilizing different research methods. We selected themes to pinpoint the most important components that identify health condition and outcome, while also giving a standard of codes that each built environment must comply with. This is where we identified four themes related to the impact of green buildings on health outcomes and dietary intake, with five studies included in each theme. The themes are: (1) green buildings and respiratory diseases (2) green buildings and mental health, (3) green buildings and dietary intake, and (4) green buildings and physical activity level.

3.1 Theme I: Green buildings and respiratory diseases

Green buildings have been shown to have a positive impact on various respiratory conditions, including chronic respiratory diseases such as asthma. Renovating homes to be more compliant with green building standards such as LEED certifications as well as improving ventilation and air quality has shown better respiratory outcomes for residents.[12,15] Residents of green buildings reported fewer respiratory symptoms and used less asthma medication compared to these living in conventional buildings. A study conducted in the United States found that green buildings were associated with improved indoor air quality, which can reduce the risk of asthma and other respiratory diseases.[16] Similar outcomes in relation to increased exposure to green spaces and respiratory disease can also be found specifically among children.[17] See Table 1 for list of studies and main outcomes in theme I.

3.2 Theme II: Green buildings and mental health

Mental health and occupancy satisfaction are key considerations when assessing the positive impact of green buildings

and spaces on individuals' environments. Multiple studies have examined the short and long-term satisfaction of the buildings' occupants. Takayama et al. (2014)[18] found that individuals that spent more time in green spaces had lower cortisol levels (a stress and immune response hormone) and reported better mental health. The study concluded that exposure to green spaces was associated with reduced levels of stress and improved mental health outcomes.[18] A view of green spaces alone could have as much positive influence as access does, on mental health, positive influences are shared in terms of satisfaction between those that use the green spaces and those that enjoy the views.[19] Additionally, exposure to natural daylight alone in green buildings has also been associated with improved mental health outcomes and increased productivity.[20]

Few studies had reported no significant psychological improvement among green building residents in comparison with those who reside in traditional non-green buildings.[16,21] See Table 2 for list of studies and main outcomes in theme II.

Table 1. Green buildings and respiratory diseases

Author	Purpose of Study	Variables	Main Outcome
Worden et al., 2022[12]	To identify opportunities for promoting health within green buildings.	- LEED certification - Health promotion	Green building developers must be intentional in their selection and application of LEED strategies to benefit from their full potential health value.
Allen et al., 2016[15]	The basics of green building designs and their effects on health in relation to indoor air quality and environments.	- Health - Building design	Better health outcomes in green buildings compared to non-green buildings.
Hanski et al., 2012[17]	How a decrease in biodiversity may influence asthma and other related chronic disease.	- Biodiversity - Allergic disposition	Declining biodiversity could worsen allergies by affecting skin bacteria diversity, emphasizing the crucial role of biodiversity in public health.
Thatcher et al., 2012[16]	Examine volatile compounds and their effects on respiratory health and disorders.	- Asthma - Volatile Compounds	Findings suggested that green buildings promote greater productivity and wellbeing.
Breysse et al., 2011[32]	Does making affordable housing greener promotes positive health outcomes.	- Green homes - Standards	Low-income housing renovations that complied with green standards showed significant improvements in the health of its residents including children.

Table 2. Green buildings and mental health

Author	Purpose of Study	Variables	Main Outcome
Boubekri et al., 2014[20]	How windows and views of green spaces can positively improve mental health.	- Windows - Space views - Physical activity	There was a positive increase in physical activity, and longer sleep duration, which helps to improve mental health.
Takayama et al., 2014[18]	How the view of green spaces effects mood of residents.	- Urban parks - Mental health - Physical activity	Views of green spaces and walking in such areas are both associated with significant improvements in mental health.
Altomonte et al., 2013[21]	Comparison of satisfaction of those that live in LEED certified buildings to those that do not.	- LEED	Those who live in LEED buildings showed slight satisfaction with air quality.
Sundell et al., 2012[34]	Comparison of two groups of employees and the impact of green buildings on psychological wellbeing.	- Mental health - Green building - Wellbeing	The study offered empirical evidence supporting the beneficial effect of green buildings on the mental wellbeing of employees who work within them.
Van Herzele et al., 2011[19]	A comparison of different neighborhoods to see the effects of green spaces on health statuses.	- Indicators of health - Mood change	The study evaluated the importance of nearby green space for people's overall well-being and suggested the need for green space to be evaluated in terms of visual proximity.

3.3 Theme III: Green buildings and dietary intake

House location and proximity to food stores is known to determine dietary patterns and food choices. Green spaces and buildings are also designed to improve food access by supporting garden usage and building location and design.[22] Some green buildings have even taken food access one step further and created on-site production facilities, such as gardens and greenhouses.[23] This may positively impact food-related behaviors in individuals residing within those communities. A randomized controlled trial investigated the impact of an environmental-level package of interventions on obesity and food-related behaviors among residents of public housing.[24] The study recruited participants from 10 public housing dwellings to assess access to healthy food options within the built environment. Over the course of one year, the intervention incorporated dietary and physical activity changes, including the introduction of farm-fresh food for the participants. Results indicated a significant improvement in eating behaviors and body weight among participants within the initial year of the intervention.[24] Another study found that increased neighborhood deprivation and decreased access to neighborhood greenspace were both significantly associated with increased odds of overweight and obesity.[25] See Table 3 for list of studies and main outcomes in theme III.

Table 3. Green buildings and dietary intake

Author	Purpose of Study	Variables	Main Outcome
Yuen et al., 2019[29]	A study on the influences of green spaces on physical activity level and a healthy dietary pattern.	- Dietary effects - Exercise	Promotion of exercise could be achieved by the design or redesign of built environment to include more parks accessible to the residents.
Bowen et al., 2018[24]	Cluster randomized controlled trial of public housing developments and their associations with unhealthy behaviors.	- Dietary risk factors - Public housing - Green homes	A year-long intervention changed eating behaviors and body weight among participants.
Block et al., 2014[23]	Food sovereignty movement and what connections will help overcome this.	- Obesity - Urban access - Food security	On-site production facilities have helped lessen the severity of food deserts and increase food production in areas of need.
Pearson et al., 2014[25]	Association between lack of access to green spaces and an increased risk of obesity.	- Obesity - Walking	Obesity was often associated with lack of access to spaces that readily promoted physical activity such as green spaces or parks.
Lovell et al., 2013[35]	Review of a strategy for supplying ecosystem services through a participatory planning process targeting green infrastructure.	- Food insecurity - Green infrastructure	Greening projects approach are likely to benefit in the urban residents and the broader public in the long term.

Table 4. Green buildings and physical activity level

Author	Purpose of Study	Variables	Main Outcome
Pearson et al., 2021[27]	How safety is associated with physical activity levels and health of individuals.	- Green space - Safety	Perceived safety in one's neighborhood may influence stress and physical activity.
Boulos et al., 2021[26]	Are physical activity and its health gains dependent on location-specific factors.	- Green space access - Physical activity	More physical activity is associated with access to green spaces.
Yuen et al., 2019[29]	A study on the influences of green spaces on physical activity level and a healthy dietary pattern.	- Dietary effects - Exercise	Promotion of exercise could be achieved by the design or redesign of built environment to include more parks accessible to the residents.
Mansor et al., 2014[36]	Do green spaces promote healthy lifestyles and physical activity.	- Health benefits - Physical activity	Green space in the built environment is a significant health promotion agenda that improves the urban quality of life.
Rahman et al., 2011[28]	How built environment impacts access to nutritious food and physical activity levels.	- Safety - Childhood obesity	To prevent onset of overweight or obesity, individuals need safe places to be active and local markets that offer healthy food items.

3.4 Theme IV: Green buildings and physical activity level

Consistent and enjoyable physical activity is a vital component to improving or maintaining individual's health status.[6,26] Physical activity and diet go together making each an important indicator of health status. Studies had indicated that access to green spaces has been linked to increased physical activity in both children and adults.[27–29] Creating a safe space to get outside and be active can also promote healthy habits that can reduce the risk of obesity and overweight.[27–29] Rahman et al. (2011)[28] reported that built environment impacts access to nutritious food and physical activity levels among children. A similar study proved that promotion of exercise can be increased by creating more green spaces that are easily accessed by residents within the area or community.[29] The study also further supported the use of green spaces with increased vegetation may promote higher physical activity levels.[29] See Table 4 for list of studies and main outcomes in theme IV.

4. Discussion

Healthy People 2030 has an environmental goal that is to promote healthier environments to improve health.[30] This goal includes four objectives on neighborhood and built environment: (1) reduce the number of toxic pollutants released into the environment; (2) reduce health and environmental risks from hazardous sites; (3) reduce the number of days people are exposed to unhealthy air; and (4) increase the proportion of schools with policies and practices that promote health and safety.[30] Currently, only one objective (objective 1) has been met in the area of built environment. This improvement in the built environment has largely been helped by the establishment of green spaces and the creating of green buildings.

In this review, we examined the influence of green buildings on an individual's health outcome and dietary intake. Our review showed a positive association between green buildings and health conditions in general. A majority of the studies addressed the impact of green buildings and the built environment on respiratory diseases and physical activity. Very few studies examined the impacts, specifically the long-term one, on dietary risk factors and obesity. Our findings suggested an association between green buildings and improving specific health conditions such as asthma, depression, and obesity. This positive association may be due to improvements of living conditions in the homes such as improved air circulation, water fixtures, and geothermal heating or cooling.[31,32] There was also a remarkable association between green building and risk of respiratory diseases, a systematic review of 36 studies found similar finding in which living in green buildings were associated with a lower risk of respiratory diseases, an improved in indoor air quality, and lower levels of indoor pollutants.[15] Which further justified our findings on green spaces and respiratory diseases. Promoting green buildings establishment can be utilized as a management tool to decrease rates of respiratory disease in high-risk areas.

Our review indicated green building design also reduced obesity rate and encouraged physical fitness, as well as suggested a positive impact on food environment. We took proximity to green spaces and buildings into consideration for determination of food environment and we concluded that there was an increase in healthier food options within green communities. Thus, concluding that access to a green space may lower the risk for obesity, given adequate intended usage. Increasing physical activity and improving food environment are important benefits to living in green buildings or near green spaces which can be utilized to reduce overweight and obesity. Furthermore, in any urban amenity design, creating an access point to places of physical activity such as a park is possible and crucial in supporting physical activity behavior among residents.

Nonetheless, our results must be interpreted with caution and several limitations should be borne in mind. One such being that the selected research was chosen in only that of English origin. The study was limited to recent publications spanning the last ten years and no current year research was used. Our data within the study was only on that of those that lived amongst green buildings and was not compared to those that did not. To comprehensively examine the association between green spaces, health outcomes, and dietary intake, researchers should undertake a longitudinal cohort study or a randomized controlled trial. Such studies would enable the identification of specific factors within the home environment that could potentially impact health conditions. For instance, researchers could examine variables such as noise intensity, dining design, and lighting, all of which may play a role in influencing health outcomes.

Moreover, it is imperative to establish health indicators that are directly related to the home environment. These indicators would serve as crucial metrics for monitoring residents' health status in both green and non-green buildings. Health indicators could include measures of indoor air quality, levels of physical activity, dietary patterns, and mental well-being. Researchers could also establish a study where participants living in green buildings are compared to those living in conventional buildings. Health indicators such as mental health scores or physical activity levels could be measured and compared between the two groups over an extended period. By monitoring these health indicators, researchers can

gain insights into the potential health benefits associated with living in green spaces and buildings. Additionally, incorporating objective measures such as air quality assessments and noise level recordings would provide further insights into the environmental factors contributing to health outcomes.

5. Conclusion

Built environment can directly influence an individual's health and eating behaviors. Green buildings are a clean way of reducing impacts on health and the environment. Our study highlights the potential of green buildings to positively impact health outcomes and dietary habits, aligning with Healthy People 2030 objectives.[30,33] While progress has been made in reducing environmental risks, opportunities remain for improvement, particularly in addressing built environment. Our study found a promising association between green buildings and various health conditions, such as respiratory diseases, depression, and obesity, attributed to improved living conditions and healthier food environments. Moving forward, longitudinal studies are needed to identify specific factors within green buildings influencing health outcomes. Establishing robust health indicators related to the home environment is essential for monitoring residents' wellbeing. By leveraging these insights, policymakers, urban planners, and researcher can harness the potential of green buildings and spaces to promote population health and mitigate the burden of chronic diseases.

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Authors contributions

Dr. AA was responsible for study design and conception. MK searched the literature and drafted the manuscript. Dr. AA and MK analyzed the data and interpreted the results. All authors read and approved the final manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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