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Linking energy policy, energy insecurity, and health outcomes

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Energy insecurity poses a global challenge with far-reaching social equity and health implications. This paper provides a comprehensive perspective on the relationship between energy insecurity and health outcomes in developed countries. Existing research has identified associations between energy insecurity and various physical and mental health outcomes. Moreover, climate change can exacerbate the adverse health consequences of energy insecurity, disproportionately affecting vulnerable populations. Based on a review of existing literature, this paper identifies several knowledge gaps, proposes future research directions, and discusses data challenges faced by researchers in measuring energy insecurity and assessing the health impacts of existing programs that tackle energy insecurity. Furthermore, the paper highlights the importance of fostering collaboration among different governmental agencies and other sectors to enhance energy insecurity program management and data collection for program evaluation.

KEYWORDS

energy insecurity, energy justice, health, energy policy, climate change

1. Introduction

Energy insecurity is a pressing issue globally. It can be broadly defined as the inability to meet basic household energy needs (Hernández, 2016).[1] This multidimensional issue is deeply intertwined with larger structural challenges that reflect and reinforce the inequalities based on socioeconomic status, race, ethnicity, and other social dimensions, all of which may contribute to adverse health outcomes (Hernández, 2016; Bednar and Reames, 2020). A growing body of literature has explored the interconnections between energy insecurity and health (Cook et al., 2008; Hernández, 2016; Simcock et al., 2017; Oliveras et al., 2021; Pan et al., 2021; Liu et al., 2022). In response, many developed countries have implemented various energy and housing policies to address household energy insecurity. However, given the complex interplay of structural challenges with energy security, the mechanisms through which energy insecurity affects various health outcomes remain inadequately understood (Hernández, 2016). Additionally, little is known about whether and how existing policy tools that tackle energy insecurity effectively address its related health risks, impeding informed future program design. This paper synthesizes the knowledge accumulated over the past decade regarding the relationship between energy insecurity and health, with a focus

1 While similar terms like "energy poverty," "energy access," and "energy vulnerability" are used in the literature to describe domestic energy deprivation (Brown et al., 2019), we adopt "energy insecurity" in this paper because the definition of "energy insecurity" we follow (Hernández, 2016) is broad enough to capture various levels of energy difficulties that different households face in the developed country context. This spectrum of challenges ranges from the lack of access to basic modern energy services (i.e., "energy poverty") to the lack of access to affordable, reliable, and sustainable energy (i.e., "energy access").

on developed countries. By examining existing literature from energy and health journals, we identify knowledge gaps and propose future research directions and practical interventions to address the health risks associated with energy insecurity.

2. Adverse health consequences of energy insecurity

Energy insecurity poses significant health risks to individuals, stemming from two major causes as discussed in the literature: (1) a household's inability to afford enough energy to meet essential needs (Hernández and Siegel, 2019; Bednar and Reames, 2020; Cong et al., 2022), and (2) lack of access to reliable and resilient power infrastructure (Ji et al., 2016; Brown et al., 2019). Below we summarize how they may affect individual health in the context of developed countries based on previous research.

2.1. Household's inability to afford essential energy needs

Low-income households often struggle to pay utility bills and may fall into arrears, leading to difficult choices like sacrificing necessary expenses for medication or food to cover energy costs (Bhattacharya et al., 2011; Cong et al., 2022; Shan et al., 2022). In the United States, for example, 25.8 million low-income households face a high energy burden (i.e., spend more than 6% of income on energy bills), and 15.4 million of them experience a severe energy burden (i.e., spend more than 10% of income on energy bills) (Drehobl et al., 2020). Moreover, specific demographic groups, such as pensioners, the unemployed, and those with disabilities or young children, are more susceptible to domestic energy deprivation due to their unique energy needs to keep essential medical services or equipment (Bouzarovski and Petrova, 2015). These households usually have higher-than-average energy demand, exceeding their limited income and increasing the risk of utility shut-offs. Consequently, these vulnerable households may live in unhealthy or unsafe indoor temperatures or be unable to sustain essential medical services and equipment.

Energy insecurity due to households' inability to afford essential energy needs can adversely affect physical and mental health, increasing the likelihood of acute diseases and worsening chronic health conditions. Previous studies in developed countries have found energy insecurity is associated with respiratory and mental health outcomes, including asthma, pneumonia, diabetes, hypertension, depressive disorders, and poor-quality sleep (Shenassa et al., 2007; Cook et al., 2008; Liddell and Morris, 2010; Hernández and Siegel, 2019; Jessel et al., 2019; Memmott et al., 2021; Oliveras et al., 2021).

2.2. Lack of reliable and resilient power infrastructure

Energy insecurity can also arise from the lack of reliable and resilient power grid infrastructure, which may impact health negatively (Bouzarovski and Petrova, 2015). While the link between inadequate grid infrastructure and health risks has been evident and prevalent in developing countries (Jenkins et al., 2016; Banerjee et al., 2021; Nawaz, 2021; Pan et al., 2021; Zhang et al., 2021; Li et al., 2022), this issue manifests as unequal access to reliable power infrastructure in developed countries, disproportionately affecting low-income and minority communities (Bouzarovski et al., 2016; Bouzarovski and Tirado Herrero, 2017).

Research using county-level data or household-level data has demonstrated that lower-income and racial minority communities experience more frequent and prolonged power outages in the US (Mitsova et al., 2018; Xu and Tang, 2020; Azad and Ghandehari, 2021; Nejat et al., 2022). These disadvantaged groups and families with young children tended to have lower tolerance for service disruptions after recent hurricanes or storms in Florida, Louisiana, Purto Rico, and Texas and experienced more hardship during power outages, such as difficulties with getting access to healthcare services and medication (Mitsova et al., 2018, 2021; Coleman et al., 2020). However, these studies only establish associations between energy insecurity and access to medical services, and more rigorous analyses are needed to determine the direct link between the lack of reliable power supply and broader physical and mental health impacts.

3. Climate change exacerbates the adverse health consequences

The increasing frequency of extreme weather events and natural disasters due to climate change can exacerbate the negative health impacts of energy insecurity on vulnerable and socially marginalized populations as it can affect both causes of energy insecurity identified in Section 2 (Shonkoff et al., 2011; Smith et al., 2013; Reames, 2016; Bouzarovski and Simcock, 2017; Benevolenza and DeRigne, 2019; Longden et al., 2021). At the household level, extreme temperatures, either too cold or warm, create additional energy burdens for low-income households as they need to increase the usage of their heating/cooling devices, which leads to higher energy bills. Vulnerable households may have health risks like heatstroke or hypothermia as they limit energy consumption to cope with tight income constraints (Jessel et al., 2019; Thomson et al., 2019; Cong et al., 2022; Shan et al., 2022).

Furthermore, the impact of more frequent extreme weather events and energy service disruptions due to inadequate energy infrastructure, disproportionately affects specific vulnerable groups, such as the poor, the elderly or disabled, family with young children, and substance abusers (Mitsova et al., 2018; Benevolenza and DeRigne, 2019; Azad and Ghandehari, 2021; Nejat et al., 2022; Rodríguez et al., 2022). Exposure to energy service disruptions increases their levels of mental, emotional, and physical stress. Consequently, climate change is likely to reinforce existing socioeconomic disparities, leaving low-income, minority, and other marginalized groups burdened with greater economic and health challenges unless proactive policies are implemented to address equity concerns (Shonkoff et al., 2011).

4. Discussion

Existing literature has been trying to establish the connection between household energy insecurity and adverse physical and mental health outcomes and calls for proactive policies to address energy insecurity and its associated health risks. However, little is known about the effectiveness of policies or programs that have been implemented to address energy insecurity and there lack of studies on the health impacts of these initiatives. Furthermore, while previous research has identified associations between energy insecurity and health risks, there is a need for more rigorous causal analyses to fully comprehend the mechanisms through which energy insecurity affects various health outcomes. To bridge these research gaps, we propose several future research directions and recommend improvements for practices.

4.1. Challenges and opportunities for future research

4.1.1. Developing a comprehensive definition and measurements of energy insecurity

Energy insecurity is a complex issue intertwined with broader aspects of inadequate housing, material and infrastructure deprivation, and neighborhood disadvantages (Hernández, 2016). To conduct a more thorough investigation of energy insecurity, it is crucial to establish a comprehensive definition that captures its multiple dimensions and guides the development of appropriate measurements.

Notably, considerable efforts have been made toward creating a holistic definition and framework of household energy insecurity (Bouzarovski and Petrova, 2015; Gouveia et al., 2022; Scheier and Kittner, 2022). For example, Thomson et al. (2019) developed a conceptual diagram encompassing vulnerability to excessive indoor heat while considering related aspects like house features, adaptability to extreme weather, and sensitivity to adverse consequences. Additionally, there has been ongoing work to develop indices and map vulnerability, capturing various facets of energy insecurity in the US and European countries. The Structural Energy Poverty Vulnerability (SEPV) index by Recalde et al. (2019) summarizes structural determinants of energy poverty in the European Union, revealing geographical patterns and their impact on health. The census tract level data provided by the Climate and Economic Justice Screening Tool,[2] presents an opportunity to create a similar index for energy insecurity in the US, considering structural factors while connecting them to climate change and health outcomes.

However, the limited availability of large-scale high-resolution energy data is still a significant roadblock for researchers to measure some dimensions of energy insecurity. Most research so far has focused on measuring energy affordability using household energy burden or ability to pay (Memmott et al., 2021). There has been scant research on energy-limiting behaviors, measured as the time of use or the energy consumption change in response to outdoor temperatures (White and Sintov, 2020; Oliveras et al., 2021; Cong et al., 2022). Availability of data for energy-limiting behaviors and other measurements of ability to pay, such as utility disconnections or bill arrears, is often restricted due to proprietary ownership by utilities or household-level survey data not disclosing high-resolution geographical information (e.g., the US Residential Energy Consumption Survey or other protected survey data collected by researchers). To facilitate research on energy insecurity and its related outcomes, it would be helpful for researchers, utilities, and government agencies to collaborate and seek better data-sharing or open-data practices in the future.

In addition to household-level energy affordability, the lack of access to reliable and resilient power infrastructure is an important dimension of energy insecurity, as discussed in previous sections. To measure this dimension, web scraping outage data from utility live outage maps (Shan et al., 2022) may present an opportunity for researchers to obtain geolocation-specific power outage and recovery data during extreme weather events and normal operations.

4.1.2. Assessing the impacts of energy justice programs on health outcomes

Another area requiring future research is the assessment of health impacts associated with a diverse range of energy programs aimed at addressing various aspects of energy insecurity. For example, within the current policy landscape of the US, these initiatives are implemented by different government agencies and utilities. They encompass utility bill assistance, financial incentives for adopting energy efficiency, clean energy, and upgrades that improve resilience to extreme weather, as well as dissemination of energy information and regulatory measures (Brown et al., 2019). There has been research evaluating participation in some of these programs and their effectiveness in reducing energy burden. Integrating relevant health outcome data, future research can further investigate their efficacy in enhancing low-income households' physical and mental health and examine whether and how they complement each other to mitigate the health risks stemming from energy insecurity.

However, accessing high-resolution health data also poses challenges, as it is collected and managed by hospitals or health departments at various levels of government with restricted public access. Therefore, establishing better data-sharing mechanisms between researchers, health departments, and hospitals is essential to facilitate such program evaluation.

4.2. Implications for practice: forging collaboration to enhance program management and data collection across government agencies and sectors

Addressing energy insecurity and its health impacts requires collaboration among various departments, including housing, health, human services, energy, and emergency management (Middlemiss and Gillard, 2015). These departments are managing various energy and housing programs separately, which increases

2 https://screeningtool.geoplatform.gov/en/methodology#energy-burden

the difficulty of data collection for program evaluation. To facilitate data collection for program evaluation, interdepartmental partnerships can be established. For instance, in the US context, the Centers for Disease Control and Prevention (CDC), the Department of Housing and Urban Development (HUD), and the Department of Energy (DOE) can work together to establish and enforce energy efficiency standards for HUD-subsidized housing. They can also collaborate to develop programs like the Enterprise Green Communities Criteria and Certification,[3] which provides a framework to ensure that low-income housing is healthier, more efficient, and incorporated into the fabric of communities, promoting resident well-being and sustainability. In the program design phase, collaborative data management arrangements should be developed to collect program implementation and performance data for future evaluation.

Another area requiring collaboration is integrating climate change mitigation and adaptation programs. By connecting natural disaster mitigation initiatives with efforts that promote energy efficiency and carbon reduction, we may better address the disproportionate economic and health impacts of climate change on vulnerable populations. Achieving this objective requires collaboration between emergency management and energy/environmental departments at different levels to formulate and implement proactive policies that address both disaster resilience (e.g., building retrofitting to mitigate natural disaster risks) and energy insecurity (e.g., building energy efficiency upgrades). Community-based organizations, advocacy groups, and residents' input are also vital in this process. These collaborative efforts will streamline data gathering and management for effective program implementation and evaluation.

3 https://www.greencommunitiesonline.org/introduction

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

TT and HK conceptualized the research, conducted the literature review, and wrote the paper. HK collected the data. TT edited the paper. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) TT declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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