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The Impact of Climate Change on People Living with Diabetes: A Scoping Review

ABSTRACT

Objective: There is substantial literature detailing the interaction between climate change and diabetes incidence, prevalence, and development. However, there is limited understanding on the impact of climate change on People Living with Diabetes (PWD). This scoping review describes the impact of climate change on morbidity and mortality for PWD.

Materials and methods: The scoping review was conducted between November 2022 and February 2023, using articles published in PubMed Central and Google Scholar databases. Articles published from 1970 to 2022 with the following key terms "diabetes", "type 1 diabetes", "type 2 diabetes", "climate change", "global warming", and "natural disaster" were reviewed.

Results: A total of 13,838 articles were identified and reviewed. After applying the review criteria, 42 applicable articles were included in the scoping review. PWD are impacted directly by climate change-induced events including extreme temperatures, air pollution, and natural disasters. Difficulty in storing insulin, maintaining special diets, and accessing diabetes supplies are indirect results of the climate crisis on people with diabetes leading to adverse outcomes such as increased risk of hospitalizations, morbidity, and mortality.

Conclusions: Environmental hazards due to climate change increase morbidity and mortality for PWD. Policies that address the interconnection between the two phenomena would improve global diabetes population health. Future research should explore potential solutions to addressing this crisis across multiple populations and settings. (Clin Diabetol 2023; 12; 3: 186–200)

Keywords: diabetes, climate change, natural disaster, global warming

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Introduction

Climate change is arguably one of the biggest health threats today and is estimated to cause approximately 250,000 additional deaths per year between 2030 and 2050 [1, 2] , likely caused by thermal stress, malnutrition, infectious diseases, extreme weather events, wildfires, displacement, and so on [3–8] . The increase in global temperatures has strongly influenced the quantity and variability of natural disasters [7]. Natural disasters directly impact communities through hurricanes, floods, and raging wildfires [7, 9]. Climate change significantly increases human exposure to environmental hazards such as heatwaves and extreme heat events [10], drought, wildfires, and extreme weather events such as storms and hurricanes [11]. Furthermore, climate change increases air pollution [12] and reduces air quality [13–15]. These events lead to an increased risk of displacement [16], medical and/or food supply shortages [17, 18], hospitalizations [19, 20], chronic complications [13], and death [13, 21].

Environmental diabetology refers to the study of how geophysical phenomena impacts a person living with diabetes. Environmental diabetology explores environmental effects on diabetes metabolic control, supplies (e.g., glucometers and insulin pumps), medications, and access to care [17].

Many of the events induced by climate change can have both direct and indirect effects on an individual's blood glucose levels, leading to poor glycemic control. Individuals may experience hypoglycemia, hyperglycemia, and diabetic ketoacidosis (DKA) events [22]. Worsened glycemic control in diabetes patients has been documented following earthquakes [17], hurricanes, [23] and after exposure to colder temperatures [24].

Diabetes affects one in ten people globally [25], and the number of people living with diabetes (PWD) has quadrupled in the last 30 years [26]. These staggering numbers highlight a growing population of individuals at increased risk from the adverse effects of climate change.

Much of the published literature on environmental diabetology is related to the increased incidence and prevalence of diabetes; [27, 28]. In this scoping review, we seek to understand the impact of climate change on PWD.

Materials and methods

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) — Scoping Reviews guidelines [29] following the Arksey and O'Malley's methodologic framework [30] (Suppl. Tab. 1–2).

Scoping review question

How does climate change impact people living with diabetes?

Protocol and eligibility criteria

The scoping review search terms used by reviewers included type 1 diabetes OR type 2 diabetes OR diabetes AND climate change OR global warming OR natural disasters OR environmental justice in PubMed Central and Google Scholar databases (Tab. 1). The terms "environment" and "physical environment" were purposefully excluded from the search criteria because preliminary searches using those terms retrieved a broad array of papers outside the scope of the review, such as metabolic and hormone pathway processes leading to the development of diabetes rather than how the factors of climate change affect the lives of PWD. Initially, the authors agreed upon using synonyms and search terms that aligned with the global warming phenomenon, climate change, and natural disasters, to ensure a targeted review. The authors decided to perform a second search utilizing global warming as a search term, to capture any newly published studies and to make sure no major papers that used global warming as a key term were missing from the search.

Table 1. Inclusive Search Criteria

Search	Search criteria
First search period: November 29th — Dec 16th 2022	
1	Type 1 diabetes and climate change
2	Diabetes and climate change
3	Type 1 or type 2 diabetes and climate change
4	Type 1 or type 2 diabetes and natural disaster
5	Type 1 diabetes and environmental justice
6	Diabetes and environmental justice
7	Type 1 or type 2 diabetes and environmental justice
8	Type 1 or type 2 diabetes and environmental injustice
9	Diabetes and environmental racism
10	Type 1 or type 2 diabetes and environmental racism
11	Diabetes and humanitarian crisis
12	Type 1 or type 2 diabetes and humanitarian crisis
13	#3 and #4
Second search period: Feb 1–7 2023	
1	Diabetes and global warming

Human randomized controlled trials, non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies, case reports, cross-sectional, mixed methods, and case series published between 1970–2022 in the English language were eligible for inclusion. Animal studies and studies not in English, and that were outside of the established timeframe were excluded from this review. Additionally, studies that did not reference diabetes specifically, described environmental impacts broader than climate change or natural disasters, or described diabetes incidence rather than the impact on people already living with diabetes were excluded.

The first (EO), second (HH) and third (AM) authors independently reviewed the titles and abstract from an initial search conducted between November 29th through December 16th, 2022. With input from a senior author (OE), all authors resolved any disagreements via consensus discussion. A total of 10,516 articles emerged from using the aforementioned search terms, except for global warming. After applying the inclusion and exclusion criteria, the number of eligible articles

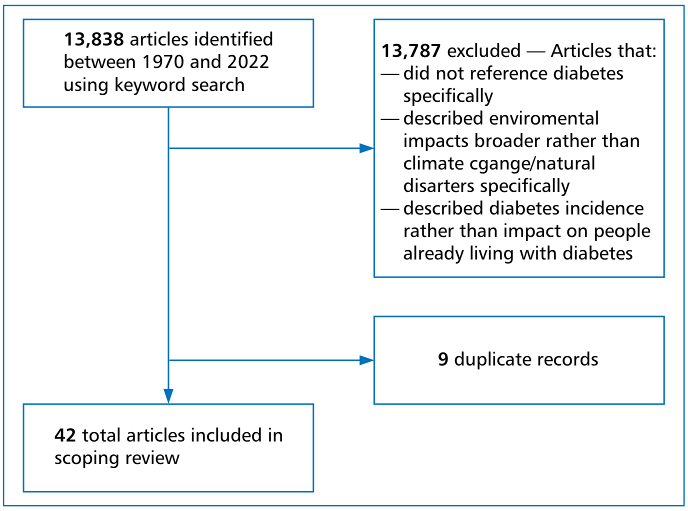

Figure 1. Scoping Review Flow Diagram

was reduced to 340 following title reviews. Thereafter the first three authors screened the abstracts of eligible articles resulting in 40 studies included in the review. An additional review was conducted from February 1st to February 7th, 2023, with an emphasis on global warming and diabetes. Similar exclusion criteria were applied for the first search. Search terms included diabetes AND global warming. This search yielded 3322 articles from PubMed and Google Scholar. After examining these articles, and applying inclusion and exclusion criteria, two additional articles were included in the review (Fig. 1). Articles included in this review highlight examples of how changes in environmental factors can affect PWD.

Results

A total of 42 studies were reviewed in this scoping review. The majority of studies (43%) included in this review used a time series study design. Other common study designs were cohort, case-control, case-crossover, cross-sectional, qualitative, and mixed methods. Of the 42 reviewed studies, 86% reported statistically significant findings or associations in their results, whereas 10% reported no significant findings, and 5% reported qualitative results. A summary of study characteristics including study design and major findings is highlighted in Table 2. The authors read through the methods and results of the selected studies and categorized these based on the nature of the study [extreme temperatures, air pollution, and natural disasters), and outcome type (morbidity, mortality, hospitalization). Major findings from this review suggest climate change impacts PWD through three major mechanisms, namely, extreme temperature, air pollution, and impact from natural disasters (Fig. 2).

Extreme temperature

Twenty-five of the reviewed studies examined the effects of extreme temperatures on PWD. Compared to the general population, PWD are more sensitive to extreme temperatures, especially heat, because of impaired thermoregulatory control, regardless of their diabetes type [31].

Diabetes morbidity increases disproportionately at high temperatures [32]. Bunker et al. [13] found that diabetes morbidity increased with heat. Additionally, extreme heat is an independent risk factor for diabetes mortality [33]. Geirinhas et al. [34] found that accumulated heat stress conditions during consecutive days preferentially preceded by persistent periods of moderate temperature, lead to higher excess mortality rather than sporadic single hot days for PWD. Li et al. [35] cite a 14.7–29.2% increase in diabetes mortality with every 1 degree Celsius increase in the daily maximum temperature over the threshold (29°C, 35°C, 33°C and 34°C for Harbin, Nanjing, Shenzhen and Chongqing, respectively). Ma et al. [33] found that short-term exposures to heat were associated with an excess burden of mortality for diabetes patients, with 4.61% of diabetes mortality attributable to heat, results from Isaksen et al. [36] demonstrate that the relative risk of death from diabetes on 99th percentile heat days was 78% greater than on a non-heat day in 45–64-year-olds. Intense and prolonged cold also adversely affect PWD [37]. Li et al. [35] found that both extremely cold and hot temperatures increase diabetes mortality in different manners. Exposure to cold spells was associated with an increased risk of hospital admission [relative risk (RR) = 1.45, 95% confidence interval (CI): 1.26, 1.66] and mortality (RR = 2.02, 95% CI: 1.37, 2.99) due to

Table 2. Scoping Review Study Characteristics

Authors last name, year of publication	Type of study	Sample size	Main findings
Shih, 2020 [52]	Case-control	N = 715,244 (199,991 elderly, 515,253 nonelderly)	Survival analysis during the two years following the typhoon indicated a significant increase in mortality in adults with an acute ischemic heart disease history who lived in the severely affected area. Mortality hazard analysis showed that among affected adults with previous cerebrovascular diseases and acute ischemic heart diseases, patients with diabetes [adjusted HR: 1.3–1.7] had significantly increased mortality rates
Kim, 2014 [73]	Case-control	178 = heat stroke, 790 = non-heat stroke	There were no significant relationships between heat stroke and diabetes mellitus: adjusted OR, 1.16; 95% CI, 0.58–2.34
Bogar, 2022 [22]	Cohort	110 = PWD, Control = 2,955	For DKA (blue trendline), we found a higher rate during cold (−17.8 to −12.2°C) vs. hot (> 43.3°C) temperature extremes; the p-value for the linear term for maximum ambient temperature was 0.003. This inverse linear relationship is consistent with a time series study of ~ 40,000 Taiwanese with diabetes, in whom DKA was more likely during colder temperatures and winter months
Leppold, 2016 [47]	Retrospective cohort	404 = PWD	There was an overall deterioration in glycemic control after the disaster, with the mean HbA1c rising from 6.77% in 2010 to 6.90% in 2012. Rural residency was associated with a lower likelihood of deteriorating control (OR 0.34, 95% CI 0.13–0.84), compared with urban residency
Pinault,2018 [74]	Cohort	20,600 = deaths from diabetes	Mention of diabetes on the death certificate resulted in higher magnitude associations between PM2.5 and CVD mortality, specifically among those who manage their diabetes with insulin or medication
Baum, 2019 [49]	Cohort	19,207 = exposed, 62337 = unexposed	Three months after the facility reopened, rates of uncontrolled diabetes were 3.6% higher in the exposed cohort than the nonexposed cohort (95% CI, 1.9–5.3%; $p < .001$). At 6 months after reopening, the differential change in rates of uncontrolled diabetes was not statistically significant
Fonseca, 2009 [18]	Longitudinal/ observational	1795 = PWD	Mean predisaster A1C levels differed between MCLNO and VA patients (mean 7.7 vs. 7.3%, $p < 0.001$) and increased significantly among MCLNO patients to 8.3% ($p < 0.001$) but not among VA and TUHC patients. A major disaster had a significant effect on diabetes management and exacerbated existing disparities. These effects may have a lasting impact on both health and economic implications
Chowdhury, 2019 [43]	Mixed methods	29 key informant interviews, 597 randomly selected ED encounters, admin records from 10,716 ED visits	There was a significant increase in patients being seen for diabetes-related complaints. Hurricanes Irma and Maria caused major disruptions to health care on St Thomas. Emphasis should be given to building a resilient health care system that will optimally respond to future hurricanes
Nishikawa, 2015 [75]	Retroactive case series	58 patients representing 7.6% of all patients with diabetes mellitus	HbA1c levels of 58 patients with periodical hospital visits did not deteriorate after the disasters. Moreover, there was no significant difference in the mean of HbA1c levels among all ages and sex throughout the year

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Table 2 (cont.). Scoping Review Study Characteristics

Authors last name, year of publication	Type of study	Sample size	Main findings
Xu, 2019 [31]	Case crossover	553,351 hospitalization records reviewed	Every 5°Celsius increase in daily mean temperature was associated with a 6% [OR = 1.06; 95% CI: 1.04–1.07] increase in hospitalization due to diabetes with lag 0–3 d. The association was greatest (OR = 1.18; 95% CI: 1.13–1.23) in those ≥ 80 y ≥ 80 y of age, but did not vary by sex, and was generally consistent by region and type of diabetes. Assuming a causal association, we estimated that 7.3% (95% CI: 3.5–10.9) of all hospitalizations due to diabetes in the hot season could be attributed to heat exposure during the study period
Alghmadi, 2021 [14]	Retrospective study	168,614 patient records	There was a statistically significant positive correlation between ambient temperature and HbA1c levels, where for each 1°Celsius increase in average weekly temperature HbA1c increased by 0.007%. Patients were at higher risk of having HbA1c ≥ 7% in high and moderate temperatures than in low temperature [$p < 0.001$, OR: 1.134, and $p < 0.001$, OR: 1.034; respectively]
Ogbomo, 2017 [10]	Case crossover	144 hospitalizations related to heat	EH was not associated with hospitalization for diabetes mellitus, in county-specific or pooled results
Hajat, 2017 [76]	Case crossover	4,474,943 consultations	Heat-related consultations were particularly high among patients with diabetes with cardiovascular comorbidities: OR = 1.171 (1.031–1.331). Patients with type-2 diabetes are at increased odds of medical consultation during days of temperature extremes, especially during hot weather
Yao, 2020 [41]	Case crossover	676,401 dispatch cases	The odds of diabetic AD and PA codes increased over time to a cumulative 24-h OR of 1.075 (1.001–1.153) and 1.104 (1.015–1.202) respectively. We found that increased PM2.5 during wildfire seasons was associated with increased diabetic outcomes over time
Ma, 2020 [33]	Time series	1,368,648 cases of death	Diabetes was only associated with extreme heat, with 4.61% (95% eCI, 0.13–7.13%) of diabetes mortality attributable to heat
Lee, 2016 [44]	Time series	97,127 pre and post hospitalizations	We identified that patients who were elderly or homeless or who had diabetes, dementia, cardiac conditions, limitations in mobility, or drug dependence were more likely to visit emergency departments after Hurricane Sandy
Knowlton, 2016 [77]	Time series	501,951 ED visits during a heat wave, 485,785 visits in the non-heat-wave reference period	ED visits for heat-related causes increased across the state [RR = 6.30; 95% CI, 5.67–7.01]. ED showed significant increases for diabetes
Davis, 2022 [78]	Case crossover	ED visits for diabetes for patients who visited Carilion Eds and lived in Roanoke and the surrounding area from Jan 1, 2010 to Dec 31 , 2017	ED visits for diabetes exhibit a U-shaped relationship with temperature, with a higher RR during cold events (RR = 1.05) vs. warm events (RR = 1.02). The RR on warm days (minimum temperature > 10°C) approaches 1.02 but peaks on the day of or the day following the elevated temperatures. The increasing health burden linked to diabetes requires new research on environmental factors that might exacerbate related illnesses
Winquist, 2016 [79]	Time series	9,856,015 ED visits	Age groups with the strongest observed associations were 65+ years for all internal causes [lag 0 RR (CI) = 1.022 (1.016–1.028)] and diabetes [lag 0 RR = 1.050 (1.008–1.095)]

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Table 2 (cont.). Scoping Review Study Characteristics

Authors last name, year of publication	Type of study	Sample size	Main findings
Arrieta, 2009 [45]	Mixed methods	Focus groups	Diabetes was identified as medical management priority after Hurricane Katrina
Lam, 2018 [20]	Time series	53,769 AMI admissions	DM patients had a higher increased risk of AMI admissions than non-DM patients during extreme temperatures. AMI admissions risks among DM patients rise sharply in both high and low temperatures, with a stronger effect in low temperatures, while AMI risk among non-DM patients only increased mildly in low temperatures
Frtiz, 2022 [32]	Time series	1,733,759 visits	The results show that on a hot day all-cause visits and visits with a diagnosis of diabetes and cardiovascular diseases increase by 8%, 25% and 14%, respectively
Geirinhas, 2020 [34]	Time series	Daily mortality records from 21 cities within MRRJ from 2000–2015	However, the highest excess of mortality was related to diabetes, particularly for women within the elderly age groups
Kondo, 2019 [63]	Time series	557 = PWD	In patients with type 2 diabetes, glycated hemoglobin decreased by 0.11% (from 7.33% to 7.22%) at 1–2 months after the earthquakes and increased thereafter. The reduction of glycated hemoglobin after 1–2 months in type 2 diabetes was associated with 'early restoration of lifelines' and 'sufficient sleep.' Disaster-associated stress levels were positively correlated with 'age,' 'delayed restoration of lifelines,' 'self-management of antidiabetic agents' and 'increased amount of physical activity/exercise,' and negatively associated with 'early restoration of lifelines' and 'sufficient sleep'
Li, 2014 [58]	Time series	Daily mortality in Harbin from Jan 1, 2008 to Dec 31, 2010 and Chongqing from Jan 1, 2011 to Dec 31, 2010	Significant associations between both extreme hot and cold temperatures and diabetes mortality were observed in Harbin and Chongqing for different lag lengths. The results indicate that both extremely cold and hot temperatures increase diabetes mortality in different manners in Harbin and Chongqing
Bai, 2016 [15]	Time series	324,034 diabetes hospital admissions	Cold and hot temperatures were also associated with a 12% (1%, 24%) and a 30% (6%, 58%) increase in diabetes-related hospitalizations, respectively. Similarly, ~ 11% of diabetes-related hospitalizations were due to total heat, virtually all of which were from mild heat
Isaksen, 2016 [36]	Time series	135,333 deaths	Mortality stratified by cause and age produced statistically significant results using both types of analyses for diabetes cause of death. Statistically significant increases in diabetes-related mortality for the 45–64 age group suggest that underlying health status may contribute to these risks
Wondmagegn, 2021 [19]	Time series	3915 cases	A climate scenario consistent with RCP8.5 emissions, and including projected demographic change, is estimated to lead to increases in heat-attributable hospital admissions, LoS, and costs of 2.2% (95% eCI: 0.5–3.9), 8.4% (95% eCI: 1.1–14.3), and 7.7% (95% eCI: 0.3–13.3), respectively by mid-century
Cruz-Cano, 2019 [51]	Time series	1205 deaths	We estimated a total of 1205 excess deaths [95% confidence interval (CI) = 707, 1702]. Excess deaths were slightly higher among men than women (632 and 579 deaths, respectively) and found only among people aged 60 years or older (1038 deaths). Most excess deaths occurred from diabetes (195 deaths)

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Table 2 (cont.). Scoping Review Study Characteristics

Authors last name, year of publication	Type of study	Sample size	Main findings
Miyamura,2022 [80]	Time series	45,482 hyperglycemic emergency hospitalizations, 62,042 hypoglycemia hospitalizations	Heat exposure was associated with hospitalizations for DKA, HHS and hypoglycemia. These results may be useful to guide preventive actions for the risk of fatal hyperglycemic emergencies and hypoglycemia
Zanobetti, 2012 [21]	Time series	3,364,868 = PWD	Mortality hazard ratios showed 1.040 (95% CI, 1.022–1.059) per 1° Celsius increase for those with diabetes, suggesting long-term increases in temperature variability may increase the risk of mortality in different subgroups of susceptible older populations
Li, 2014 [35]	Time series	Diabetes mortality data of Harbin (1 January 2008 — 31 December 2010), Nanjing (1 January 2004 — 31 December 2010), Shenzhen (1 January 2004 — 31 December 2010) and Chongqing (1 January 2011 — 31 December 2012)	After adjusting for potential confounders including air pollution, strong associations between daily maximum temperature and daily mortality from all-cause, cardiovascular, endocrine, and metabolic outcomes, and particularly diabetes, were observed in different geographical cities, with increases of 3.2–5.5%, 4.6–7.5% and 12.5–31.9% (with 14.7–29.2% in diabetes), respectively, with each 1°C increment in the daily maximum temperature over the threshold
Kim, 2022 [37]	Time series	Hospital admissions and mortality due to diabetes among all Korean residents between Jan 1. 2010 and Dec 31. 2019	Exposure to cold spells was associated with an increased risk of hospital admission [RR = 1.45, 95% CI: 1.26–1.66] and mortality (RR = 2.02, 95% CI: 1.37–2.99) due to diabetes
Mei, 2022 [81]	Time series	736,301 deaths, 70.8 ± 14.6 for Nanjing	Low relative humidity (RH) (about < 45%) was associated with increased diabetes mortality risk in Nanjing. All-cause mortality and 12.48% (95% eCI: 7.17–16.80) and 23.79% (95% eCI: 0.92–387.93) diabetes mortality in Nanjing were attributable to RH.
Poirer, 2020 [82]	Cross-sectional	13 = PWD, 30 = control	We conclude that unacclimatized, physically active, older adults with well-controlled T2D do not experience greater hyperthermia and cardiovascular strain compared to their healthy counterparts while resting in extreme heat for a brief, 3-h period.
Stieb, 2019 [39]	Cross-sectional	2014 Canadian population	Restrictive criteria, diabetes, suggested that approximately one-third of the Canadian population is more susceptible. A substantial proportion of the Canadian population exhibits at least one risk factor that increases their susceptibility to adverse effects of O_3 and $PM_{2.5}$ exposure
Ko, 2014 [46]	Cross-sectional	(N = 104,654) in the 2006–2010 Behavioral Risk Factor Surveillance System	Compared to individuals without diagnosed diabetes, those with diabetes were more likely to report that their household had a 3-day supply of water (60.1% vs. 53.0%), a 3-day supply of prescription medication (94.7% versus 89.1%), and an evacuation plan (27.0% vs. 20.6%). After adjusting for socio-demographic characteristics, the differences remained significant for having a 3-day supply of prescription medication (aPR = 1.04; 95% CI, 1.02–1.05) and an evacuation plan (aPR = 1.13; 95% CI, 1.05–1.22)

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Table 2 (cont.). Scoping Review Study Characteristics

Authors last name, year of publication	Type of study	Sample size	Main findings
Hirai, 2021 [69]	Cross-sectional	16097 = PWD, 14,277 = Control	In the age-adjusted and sex-adjusted logistic models, suboptimal diabetic control [hemoglobin A1c (HbA1c) ≥ 7%] was associated with both psychological distress and possible PTSD. After the triple disaster, non-specific mental health distress was associated with suboptimal diabetic control
Ford, 2006 [23]	Cross-sectional	A total of 1681 respondents representing 977,294 adults aged 18 years or older	About 9.0% of participants had diabetes in the New Orleans--Metairie-Kenner, La, metropolitan statistical area. A surveillance system such as the BRFSS can provide potentially useful baseline information about the numbers of people with chronic diseases and the treatment that they receive; this information can assist the medical and public health community in assessing the needs of people with chronic diseases after disasters and in planning relief efforts
Erens, 2021 [83]	Mixed methods	(*n* = 3153) and focus groups	Current public health messages appear to be insufficient, given the low level of (potentially) vulnerable adults changing their behavior during hot weather. In the context of increasingly warmer summers in England due to climate change, public health messaging needs to convince (potentially) vulnerable adults of all the risks of hot weather (not just the effects of sunlight on the skin) and the importance of heat protective measures
Travia, 2021 [48]	Mixed methods	Focus groups (N = 25), Interviews (N = 5), EMR data (N = 5997)	No significant differences were found between mean HbA1c values before and after Matthew (before Matthew: mean HbA1c 8.34 ± ± 1.87%; after Matthew: mean HbA1c 8.31 ± 1.93 %; p = .366). The period prevalence (PP) of DKA was higher after Matthew than before (before Matthew: 39 cases out of 4,025 visits, PP = .010; after Matthew: 87 cases out of 3,779 visits, PP = .023; p <.0001)
McElfish, 2016 [16]	Qualitative	Focus groups (N = 69)	Participants identified barriers at the organizational, community, and policy levels that constrain their efforts to achieve diabetes self-management

AD — ambulance dispatch; AMI — acute myocardial infarction; BRFSS — Behavioral Risk Factor Surveillance System; CI — confidence interval; CVD — cardiovascular disease; DKA — diabetic ketoacidosis; DM — diabetes mellitus; ED — emergency department; EH — extreme heat; HbA1c — hemoglobin A1c; HHS — hyperglycemic state; HR — hazard ratio; LoS — Length of hospital stay; MCLNO — Medical Center of Louisiana at New Orleans; O3 — ozone; OR — odds ratio; PA — paramedic assessment; PM2.5 — particulate matter 2.5; PTSD — post-traumatic stress disorder; PWD — people living with diabetes; RCP — representative concentration pathway; RR — risk ratio; T2D — type 2 diabetes; TUHC — Tulane University Hospital and Clinic; VA — Veteran Affairs

diabetes [37]. Xu et al. [31] estimated that 7.3% of all hospitalizations due to diabetes in the hot season were attributed to heat exposure in Brazil, and Bai et al. [15] demonstrated that cold and hot temperatures were associated with a 12% (95% CI: 1%, 24%) and a 30% (95% CI: 6%, 58%) increase in hospitalizations from diabetes, respectively. Another study found that short-term heat exposure may increase the burden of diabetes-related hospitalization, especially among the very elderly [31].

Air pollution

Four studies examined the effects of air pollution on PWD. Climate change can induce changes in air quality and has the potential to increase levels of pollutants such as ground-level ozone [38]. Air pollution impairs physiological function [39] including elevated blood glucose for adults with diabetes [40].

Exposures to smoke emitted from wildfires were found to be consistent with other findings associating fine particulate matter (i.e., particulate matter that are 2.5 microns or less in diameter — PM2.5) with increased risk of hospitalization due to diabetes [41], and Stieb et al. [39] found that individuals considered that exhibited at least one risk factor (living with diabetes) were more susceptible to adverse effects of O_3 and $PM_{2.5}$ exposure.

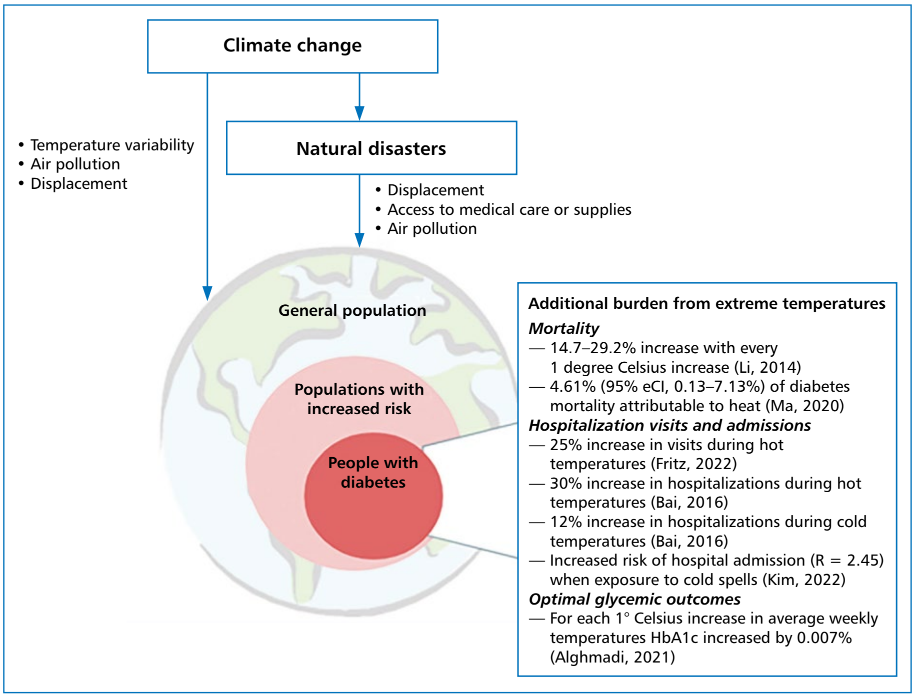

Figure 2. Impact of Climate Change on PWD

Natural disasters

Thirteen studies explored how PWD may be affected by natural disasters such as hurricanes and earthquakes. These disasters often lead to disruptions in access to medical supplies or care [18] and have the potential to damage healthcare infrastructure [13]. Additionally, in extreme circumstances natural disasters may lead to the displacement of communities [16, 42].

All of these factors may lead to increased difficulty in accessing and storing insulin, reduced access to healthy diets, and reduced glucose monitoring due to lack of supplies. Chowdhury et al. [43] found that at six and nine months after hurricanes Irma and Maria, there was a significant increase in patients being seen for diabetes-related complaints, and Lee et al. [44] reported that patients who had diabetes were more likely to visit emergency departments after Hurricane Sandy, supporting the idea that natural disasters may disproportionally affect PWD and cause medical disruptions.

Continuity of care for chronic diseases, such as diabetes, has been identified as a major concern after a natural disaster [45]. One study found that compared to individuals without diagnosed diabetes, PWD were more likely to report that their household had a 3-day supply of water, a 3-day supply of prescription medication, and an evacuation plan (27.0% vs. 20.6%) [46]. However, Arrieta et al. [45] documented inadequacies of pre-disaster preparation among individuals living with diabetes, classified as a medical management priority, and suggested pre-disaster stockpiling coupled with safe storage, and the staging of supplies in locations just outside the perimeter of a potential disaster area under imminent threat.

Leppold et al. [47] found that patients with diabetes who were affected by Japan's triple disaster (earthquake, tsunami, and nuclear accidents) experienced a deterioration in their glycemic control following the disasters, demonstrating an increase in the cohort's mean hemoglobin A1c (HbA1c) rising from 6.77% in 2010 to 6.90% in 2012. They also found that rural residency was associated with a lower likelihood of deteriorating control (OR 0.34, 95% CI 0.13 to 0.84), compared with urban residency.

Travia et al. [48] found the period prevalence of DKA was higher in the six months following Hurricane Matthew compared to before the hurricane. Rates of uncontrolled diabetes were 3.6% higher among veterans who experienced a 6-month closure in their medical center after Superstorm Sandy; however, these impacts were not significant 6 months after the center reopening [49].

Multiple studies found that mortality increased for PWD after exposure to natural disasters. Quast et al. [50] found that seniors with diabetes experienced a 40% increase in all-cause mortality in the first month after Hurricanes Katrina and Rita, Cruz-Cano and Mead [51] reported excess deaths among PWD following Hurricane Maria in Puerto Rico, and Shih et al. [52] found that after Typhoon Morakot a mortality hazard analysis showed that among affected adults with previous cerebrovascular diseases and acute ischemic heart diseases, patients with diabetes had significantly increased mortality rates [adjusted hazard ratio (HR): 1.3–1.7].

Discussion

Clinical and policy implications

As described above, climate change has several clinical implications for PWD. Several studies quantified the effects of climate change on health outcomes of individuals living with diabetes in terms of quality of life, morbidity, and mortality. Multiple studies demonstrated a relationship between exposure to heat events and increased morbidity and mortality for PWD [13, 33, 35, 36, 50–53]. More specifically, studies found increased rates of hospitalizations after exposure to a climate change-induced event [10, 15, 31, 37, 41]. Additionally, many of the environmental hazards induced by climate change have both direct and indirect effects on an individual's blood glucose levels, leading to poor glycemic control or episodes of DKA [17, 22–24, 40, 47, 49].

One of the first manuals focusing on emergency diabetes care was created by the Japan Diabetes Society following the catastrophic 2011 earthquake [54], and since then additional resources and guidelines have been created by diabetes care specialists to help coordinate and bundle resources for providers and patients [55, 56]. In the 2022 ISPAD Clinical Practice Consensus Guidelines, disaster preparedness is briefly mentioned [57]; however, recommendations from diabetes organizations for disaster-related preparedness for PWD are still lacking. Diabetes professionals should educate PWD on the impacts of climate change and make adequate care plans including sick day plans to mitigate adverse effects [39, 58, 59]. Diabetes teams should emphasize the importance of limiting exposure to extreme temperatures, staying hydrated, and ensuring adequate insulin management [15, 31, 35]. Recommendations should be appropriate to geographic location, season, and with consideration of expected natural disasters, wherever possible [57].

Outside of healthcare, a more coordinated approach from stakeholders including public health, urban planning, community-based partnerships, and disaster preparedness may be beneficial to reduce the impact of climate change on PWD [60]. Disaster preparedness plans should incorporate diabetes considerations (through insulin access, effects of extreme temperatures, etc.) so that preparedness teams are trained to effectively support high-risk individuals like PWD and outline immediate response and long-term support for PWD [61].

Future direction

This scoping review highlights the impacts of environmental hazards on PWD; these hazards such as extreme temperatures, air pollution, and natural disasters are becoming more common in several parts of the world due to climate change. Several systematic reviews have highlighted the effects from climate change induced events on PWD such as exposure to extreme temperatures and risk of hospitalizations [13, 24, 53, 61, 62].

Many of the studies in this review discuss the more immediate impacts of natural disasters on PWD, within six months to a year but do not explore the long-term effects. One study suggested that the effects of natural disasters were mitigated with access to insulin and demonstrated that glycemic deterioration long-term post-disaster can be in part due to a shortage of antidiabetic agents, largely destroyed homes, and changes in working environments [63]. Other systematic reviews have reported on the burden of chronic care management and increased hospitalizations and ED visits after natural disasters [64–66], highlighting the need for continuing management of diabetes care in these areas long term.

Additional studies examining the effects of children with diabetes who are exposed to environmental hazards induced by climate change are needed. For example, Cai et al. [40] demonstrated that medium-term exposure to ambient PM2.5 and PM10 were associated with higher FBG levels in children; however, this population of children was considered to be generally healthy and not living with diabetes.

Only a small number of studies assessed the quality of life or mental health impact of natural disasters for PWD. The independent mental health impact of diabetes [67] and natural disasters [68] are well documented, but the intersection of the two did not appear significantly in the published literature. Understanding this intersection is important to support the lived experience of PWD, further studies are needed in this area [63, 69].

Similarly, structural racism and the impact of social determinants of health predisposes racial and ethnic minorities living with diabetes to a heightened burden of climate change [70, 71]. Communities facing additional burdens of systemic racism, geographical isolation, or socioeconomic disadvantage, such as communities of color, indigenous people, the geographically isolated, and those who are socioeconomically disadvantaged may already be experiencing poor environmental quality and are less likely to adapt to climate change [72]. Supporting literature reported that a major disaster exacerbated existing disparities related to socioeconomic status, in addition to the significant effect it had on diabetes management [18].

Strengths and limitations

Strengths of this scoping review include the long study period (more than 50 years), three primary reviewers, and the review of multiple study designs. Additionally, a second review was carried out by reviewers to include additional search criteria at a later date. This search was conducted to attempt to capture all available research published in this field. This scoping review uniquely assesses climate change induced environmental hazards as well as natural disasters under one umbrella. However, this study has a few limitations. First, the quality of evidence could not be appraised because of the heterogeneity of the study types. Second, only publications in English were considered; it is possible that good-quality studies on the topic may have been published in other languages. Third, although PubMed is generally considered the most comprehensive database for medical literature, it is possible that there could be additional publications in more specialized databases. This risk is mitigated by the inclusion of articles from Google Scholar, which tends to generate much more results from searches than traditional databases. Google Scholar also does a great job of capturing grey literature.

Conclusions

Climate change increases the frequency and intensity of environmental hazards such as extreme temperatures, air pollution, and natural disasters, which increase morbidity and mortality for people with diabetes. Policies that address the interconnection between climate change and diabetes outcomes would improve global diabetes population health. Future research should explore potential solutions to addressing this crisis across multiple populations and settings.

Ethical permission

Ethical approval was not needed for this article.

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Conflict of interests

Dr. Ebekozien has been a member of the Medtronic Diabetes Health Equity Advisory Board. His organization T1D Exchange has received research support on his behalf from Dexcom, Medtronic Diabetes, Eli Lilly, Abbott, Vertex. He has received honoraria from Vertex and Medtronic Diabetes. Dr. Shah reports receiving research grants through the University of Colorado from NovoNordisk, Insulet, Tandem Diabetes Care, Alexion, and Dexcom and honoraria from Dexcom, Insulet, LifeScan, DKSH Singapore, Embecta, and Medscape LLC for consulting and speaking outside the submitted work. All other authors report no conflicts.

Supplementary Table 1. PRISMA Checklist

Section of Paper	Number	Description	Completed
Title	1	Identify report as scoping review	Yes
Abstract			
Structured Summary	2	Provide structured summary	Yes
Introduction			
Rationale	3	Describe Rationale for Review	Yes
Objectives	4	Provide an explicit statement of questions and objectives being addressed	Yes
Methods			
Protocol and Registration	5	Indicate if protocol exists and include registration number	N/A
Eligibility Criteria	6	Specify characteristics of the sources of evidence	Yes
Information Sources	7	Describe all information sources and date the most recent search was conducted	Yes
Search	8	Present the full electronic search strategy for at least 1 database	Yes
Selection of sources evidence	9	State the process for including sources of evidence	Yes
Data charting process	10	Describe the methods of charting data from included sources	Yes
Data items	11	List and define all variables for which data were sought	Yes

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Supplementary Table 1. PRISMA Checklist

Section of Paper	Number	Description	Completed
Critical appraisal of individual sources of evidence	12	If done, provide rational for conduction a critical appraisal of included sources of evidence	Yes
Summary measures	13	Not applicable for scoping reviews	N/A
Synthesis of results	14	Describe the methods of handling and summarizing the data charted	Yes
Risk of bias across studies	15	Not applicable for scoping reviews	N/A
Additional analyses	16	Not applicable for scoping reviews	N/A
Results			
Selection of sources of evidence	17	Give numbers of sources of evidence screened, assessed for eligibility and includes in flow diagram	Yes
Characteristics of sources of evidence	18	For each source of evidence, present characteristics for which data was charted	Yes
Critical appraisal within sources of evidence	19	If done present data on critical appraisal included sources of evidence [see item 12)	Yes
Results of individual sources of evidence	20	For each included source of evidence, present relevant data that were charted relating to the review questions	Yes
Synthesis of results	21	Summarize and/or present the charting results as they relate to the review questions	Yes
Risk bias across studies	22	Not applicable for scoping reviews	N/a
Additional analyses	23	Not applicable for scoping reviews	N/A
Discussion			
Summary of evidence	24	Summarize the main results	Yes
Limitations	25	Discuss limitations to scoping review process	Yes
Conclusion	26	Provide general interpretation of results	Yes
Funding	27	Describe sources of funding for the included sources of evidence	N/A

Supplementary Table 2. Arksey and O'Malley Framework

Stage	Description	Completed
1	Identifying the research question, which is generally broad in nature	Yes
2	Identifying relevant studies, a process that is as comprehensive as possible	Yes
3	Study selection, with the establishment of inclusion/exclusion criteria, based on familiarity with the literature	Yes
4	Charting the data, a stage that includes sifting, charting, and sorting information according to key issues and theme	Yes
5	Collating, summarizing, and reporting the results, which provides both a descriptive and numerical summary of the data and a thematic analysis	Yes
6*	A consultation exercise, an additional, parallel step involving key stakeholders t o inform and validate study findings	N/A

*an optional step

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