The Journal of Climate Change and Health 19 (2024) 100338

Contents lists available at ScienceDirect

The Journal of Climate Change and Health

journal homepage: www.elsevier.com/joclim

Review

Impact of climate change on rheumatic diseases: A scoping review

Tamiko R. Katsumoto[a,*], Liya Stolyar[a,b], Chathurika L. Dandeniya[c], Hong Nei Wong[d], Cristina M. Lanata[e], Titilola Falasinnu[a,f], Thomas Bush[g]

[a] Stanford School of Medicine, Division of Immunology and Rheumatology, Stanford, CA, USA
[b] Palo Alto VA Healthcare System, Palo Alto, California, USA
[c] Department of Medicine, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka
[d] Lane Library, Stanford University School of Medicine, Palo Alto, CA, USA
[e] National Human Genome Research Institute, National Institutes of Health, Bethesda, MD, USA
[f] Division of Pain Medicine, Stanford University School of Medicine, Stanford, CA, USA
[g] Santa Clara Valley Medical Center, San Jose, CA, USA

A R T I C L E I N F O

Article History:
Received 10 March 2024
Accepted 31 July 2024
Available online 3 August 2024

Keywords:
Scoping review
Climate change
Global warming
Pollution
Malnutrition
Rheumatology
Arthritogenic infections

A B S T R A C T

Introduction: Although the impacts of climate change on human health conditions are reasonably well documented, specific influences on rheumatic diseases remain incompletely characterized. The goal of this scoping review was to better understand how climate change is impacting rheumatic diseases, either directly or indirectly, as well as how climate change affects the geographical distribution of infectious diseases with arthritogenic manifestations, which will impact rheumatic disease care.
Methods: A scoping review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR).
Results: 149 papers were identified regarding the impact of climate change related exposures on patients with rheumatic diseases. The most common climate-related exposure was air pollution, with other factors including excess heat or cold, precipitation, exposure to ultraviolet light, and malnutrition. The vast majority of studies identified associations of climate related factors with increased disease activity or incidence. 105 studies were identified that addressed the influence of climate change on the observed or projected changes in the geographical range of diseases with arthritogenic manifestations spread by arthropods or environmental vectors. The majority of studies focused on dengue, Lyme disease and chikungunya and found an increase in the geographical range with climate change. A grey literature search of rheumatology organization websites suggests that the field of rheumatology remains inadequately prepared for climate change impacts.
Conclusions: The existing literature was summarized and gaps were highlighted that are deserving of further exploration such that rheumatologists can be better prepared to care for their patients, educate them on potential health harms, and advocate for policies to proactively address the climate crisis.

1. Introduction

Climate change, driven by anthropogenic emissions, poses an existential threat to humanity [1]. Despite 2023 being the hottest year on record, emissions continue to trend upwards [2]. Unprecedented upticks in heat-related deaths, food insecurity due to drought, and life-threatening infectious diseases from climate change are all being amplified in the face of inadequate action. The climate emergency is driving further social disparities, as impacts on human health disproportionately affect those who have contributed least to this issue [3,4,5].

Although the impacts of climate change and resultant extreme weather events on human health conditions are reasonably well documented [6], specific influences on rheumatic diseases remain incompletely characterized [7]. Furthermore, defining a causal role for climate change in rheumatic diseases may be less obvious, as the underpinnings of autoimmunity and inflammation are indeed complex and the evolution of disease more insidious in nature. Evidence suggests that autoimmune diseases are on the rise, as reflected in

Abbreviations: BMI, body mass index; CO, carbon monoxide; CTD-ILD, connective tissue disease-related interstitial lung disease; CONUT, Controlled Nutritional Status Score; JIA, juvenile idiopathic arthritis; KD, Kawasaki disease; NHANES, National Health and Nutrition Examination Survey; NRI, nutritional risk index; O3, ozone; OA, osteoarthritis; PM2.5, particulate matter 2.5 micrometers or smaller; PM10, particulate matter 10 micrometers or smaller; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; NO2, nitrogen dioxide; RA, rheumatoid arthritis; SSc, scleroderma and systemic sclerosis; SpA, spondyloarthropathy; SLE, systemic lupus erythematosus; UV, ultraviolet

* Corresponding author at: 300 Pasteur Drive, Suite H305, Stanford, CA 94305, USA.
E-mail address: tkatsum@stanford.edu (T.R. Katsumoto).

https://doi.org/10.1016/j.joclim.2024.100338

part by the increasing prevalence of positive antinuclear antibody (ANA) blood tests that can be associated with diseases such as systemic lupus erythematosus [8,9]. Environmental factors, such as air pollution driven by the burning of fossil fuels and wildfires, may initiate or trigger flares of autoimmune and inflammatory diseases. Extreme weather events, food insecurity and malnutrition, forced migration, and ecoanxiety are some of the downstream consequences of climate change that will impact rheumatic diseases unfavorably [10].

The changing climate is creating conditions that are altering the global footprint of various infectious diseases, including many vector-borne diseases and infections with arthritogenic manifestations that can be mimickers or catalysts of rheumatic diseases. Dengue, chikungunya and Lyme disease are growing threats that are rapidly becoming endemic in new areas. Excess cases of coccidioidomycosis are being driven by drought conditions that facilitate transmission. Understanding how climate change is impacting disease transmission and causing extended seasonality will enable more effective adaptation strategies to mitigate health impacts [11].

The global rheumatology community needs to be prepared for how our rapidly changing environment will impact rheumatic diseases as well as lead to an increased infectious disease burden, which will complicate diagnosis and management of our largely immunosuppressed patient population. Rheumatologists need to be able to identify and address the impacts of climate change on rheumatic diseases to enhance patient care and help them prepare for anticipated downstream consequences [10].

This scoping review aims to investigate the intersections between climate change and rheumatic diseases, as well as their potential ramifications on infectious diseases with arthritogenic manifestations. Specifically, the objectives are: (1) to elucidate the current understanding of the relationship between climate change, including extreme weather events and air pollutants derived from fossil fuels, and its impact on various rheumatic diseases; 2) to explore the association between malnutrition (an anticipated consequence of climate change) and its influence on the onset, severity, and outcomes of rheumatic diseases; 3) to examine the evolving changes in geographical distribution of infectious diseases with arthritogenic manifestations in the context of climate change-induced environmental shifts; 4) to identify gaps in existing literature and areas for future research regarding the effects of climate change on rheumatic diseases and infectious diseases with rheumatic manifestations; and 5) to provide valuable insights for rheumatologists to better understand and address the implications of climate change on patient care and public health strategies related to rheumatic diseases.

2. Methods

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [12] and the PRISMA Extension for Scoping Reviews (PRISMA-ScR) [13].

2.1. Research questions identified

Anticipating the various dimensions of climate change impacts that rheumatologists might encounter globally, this scoping review employed a search strategy divided into 1) climate change impacts on rheumatic diseases, and 2) climate change impacts on infections with arthritogenic manifestations.

Specifically, the following two research questions were explored:

(1) What is known about the relationship between rheumatic diseases and a) climate change (including extreme weather events), b) specific pollutants (including from fossil fuels that contribute to climate change), and c) malnutrition (that can be a consequence of climate change) on rheumatic disease?

(2) What is known about how climate change may alter geographic ranges of infectious diseases that have arthritogenic manifestations?

Table 1
Summary of search terms.

Category	Included conditions or infections
Climate change	Climate change, global warming, greenhouse effect greenhouse gas, extreme temperature, heat wave, hurricanes, cyclones, tropical storms, floods, drought, wildfires, ultraviolet light, air pollution, malnutrition
and rheumatic diseases	Systemic lupus erythematosus, rheumatoid arthritis, psoriatic arthritis, scleroderma, juvenile inflammatory arthritis, childhood Lupus, Sjogren's, myositis, gout, polymyalgia rheumatica, vasculitis, Kawasaki's, reactive arthritis, ankylosing spondylitis, interstitial lung disease associated with connective tissue disease, osteoarthritis, fibromyalgia, Behcet's, sarcoidosis
or infections with rheumatic manifestations	Alphavirus, chikungunya virus, Sindbis virus, Ross River virus, O'nyong'nyong, Semliki Forest virus, Mayaro virus, Barmah Forest virus, Dengue virus, Borrelia, Rickettsia, Aspergillus, Histoplasma, Cryptococcus, Coccidioides, Lyme

2.2. Search strategy

For the first research question, search terms were used relating to climate change or related exposures and rheumatic diseases. A variety of rheumatic diseases were included with climate change and related exposures as search criteria (hurricanes, cyclones, tropical storms, heatwaves, floods, drought, wildfires, and air pollution) in order to capture a larger number of studies that would be pertinent to the primary research question (Table 1).

The second research question sought to explore the influence of climate change on the evolving risk of infectious diseases with arthritogenic manifestations. The search criteria included studies or evidence of climate change factors associated with viral, bacterial, or fungal agents with arthropod or environmental spread that can cause arthritic manifestations (Table 1) [14-16]. The studies selected for the review process specifically addressed a change in geographical range associated with climate change.

The electronic databases PubMed and Embase were queried on July 5th, 2023, for the years 2008 to 2023. Reviews, systematic reviews, meta-analyses, and editorials were excluded. Detailed search queries are available in Appendix A. A targeted search in the Scopus database for relevant articles published in the Journal of Climate Change and Health was added on September 5th, 2023, as this journal includes pertinent literature but is not included in the Medline (PubMed) and Embase journal coverage lists.

A targeted search of the gray literature was performed employing two different strategies. A Google search was performed with the term "climate change" matched sequentially with each of the terms for rheumatic diseases and infections or vectors listed in Table 1. The search targeted original data since 2008 addressing the research questions within the first 5 screen pages of findings. A second approach consisted of reviewing the websites of 7 major international rheumatology organizations in September 2023 for any articles, position statements, newsletters, or podcasts related to climate change or related exposures.

2.3. Study selection

The Covidence systematic review platform was utilized for study screening and data extraction. Two authors (TRK and TB) independently screened the citation titles and abstracts for inclusion and

Table 2
Inclusion and Exclusion Criteria.

Category	Inclusion criteria	Exclusion criteria
Concept	Involves climate change or a climate change-related exposure	Does not involve climate change or a climate change-related exposure
	Specific rheumatic diseases included per methods	Specific rheumatic diseases were not identified per methods
	Impact on the onset, severity, serologies, outcomes or care of rheumatic diseases noted	No description of impact of the onset, severity, serologies, outcomes or care of rheumatic diseases
	Specific infectious diseases or vectors included per methods	Specific infectious diseases or vectors not included per methods
	Describes a change in geographic range of infectious disease of vector related to climate change	Does not describe a change in geographic range of infectious disease of vector related to climate change
Language	English	Not English
Timeframe	2008−2023	Prior to 2008
Article	Articles with full text	Articles with abstract only, conference posters only, case reports or full text not available

exclusion criteria. Any discrepancies were resolved by a 3rd reviewer (LS) (Table 2). These two authors (TRK and TB) then reviewed the full text for papers that met inclusion criteria and a third author (LS) resolved any discrepancies.

2.4. Data abstraction

A data abstraction form was employed to record publication date, geographical location, study design, climate change-related exposure, rheumatic disease, organ, or laboratory test affected, infectious disease or vector, and outcomes. The full text for papers were independently reviewed by authors (TB, TK, LS, CD), with discrepancies resolved by the reviewers with a final decision by one author (TB). Results were organized for analysis using an Excel spreadsheet.

3. Results

A total of 12,077 records were identified with the database literature search using terms that pertained to climate change, rheumatic diseases, and infectious diseases with arthritogenic manifestations (Fig. 1). Based on the eligibility criteria, 254 studies were identified for data extraction.

The study years for the papers regarding rheumatic diseases and infections are shown in Fig. 2. There was a steady increase in papers in recent years, particularly those focused on rheumatic diseases.

The categorization of geographical locations of the studies was adapted from the United Nations M49 Standard of regions and subregions [17] with the addition of the Mediterranean Basin [18] (Fig. 3). For research question 1, the included publications on rheumatic diseases consisted of 149 studies. Most of the studies were from Asia (*N* = 52, 35 %), and the Global South was notably less well represented (Fig. 3A and Appendix B). For research question 2, the included publications on infectious diseases with arthritogenic manifestations consisted of 105 studies, with the largest number of studies from North America (*N* = 30, 29 %) (Fig. 3B and Appendix C).

3.1. Rheumatic diseases

One hundred and forty-nine papers were identified regarding the impact of climate change related exposures on patients with a variety of rheumatic diseases [19-167]. Of the seventeen different rheumatic diseases included, the most well represented conditions were rheumatoid arthritis (RA), systemic lupus erythematosus (SLE), Kawasaki disease (KD) and systemic sclerosis (SSc) (Appendix D). Studies were conducted in a wide variety of geographical locations. Africa was underrepresented, with only 1 study.

The impacts of climate change related exposures on rheumatic diseases are listed in Table 3. The most common exposure was air pollution, with other factors including excess heat or cold, precipitation, exposure to ultraviolet (UV) light, and malnutrition. Of note no papers were identified that specifically focused on extreme weather events (i.e., hurricanes, floods, drought) from climate change.

Each study was reviewed to determine if there was an impact of the factors related to climate change on disease activity or incidence. Indicators of disease activity included changes in direct measures of disease activity, changes in the rate of hospital admissions and/or ambulatory visits, changes in laboratory serologies, and changes in the mortality rates. Most studies demonstrated an association with climate related factors and increased disease activity or incidence.

The specific climate related factors associated with each rheumatic disease are listed in Table 4. The table includes a guide to references for each disease. More details about individual studies can be found in Appendix B. Key studies that illustrate the interaction between climate change driven environmental factors and rheumatic diseases are discussed below.

3.1.1. Rheumatoid arthritis

3.1.1.1. Pollution. Seventeen studies on RA found an association of pollution with the incidence, prevalence, and severity of disease, including disease activity and frequency of disease flares (Table 4). Six of these studies were from China, Taiwan, and South Korea, countries which have exceeded the WHO's recommended levels for PM2.5 pollutant concentrations according to the World Air Quality report [168]. Regarding the onset of RA, anti-citrullinated peptide antibodies are highly specific autoantibodies in RA. Four studies [25,33,34,30] found an association with air pollution, specifically PM2.5, with the onset (as determined by the development of anti-citrullinated peptide antibodies or clinical diagnosis) or severity of rheumatoid arthritis. Four studies found no association of pollutants with RA incidence [50,51], RA flare [49], or autoantibodies and joint symptoms [48].

3.1.1.2. Malnutrition. Food insecurity and malnutrition are predicted to become increasingly problematic, due to economic hardship exacerbated by extreme weather events and forced migration as well as by other factors related to climate change, such as declining crop yields [169,170]. Six studies on malnutrition and RA were identified. In a cohort of 1976 RA patients from the NHANES database, the prevalence of malnutrition ranged from 18.8 % (based on the Controlled Nutritional Status Score, CONUT) up to 26.6 % (based on the nutritional risk index, NRI) and was strongly associated with an increased risk of all-cause mortality [36]. In a Brazilian cohort, almost one-third of patients demonstrated nutritional impairment which was associated with increased disease activity and loss of function [38].

3.1.1.3. Temperature changes and UV exposure. Temperature changes had mixed effects on RA, with two studies citing worsening arthritis with cold exposure [43,44] and one study showing associations of extremely high diurnal temperature ranges with an increased risk for RA hospitalizations [45]. A review of 14,401 patients with rheumatic

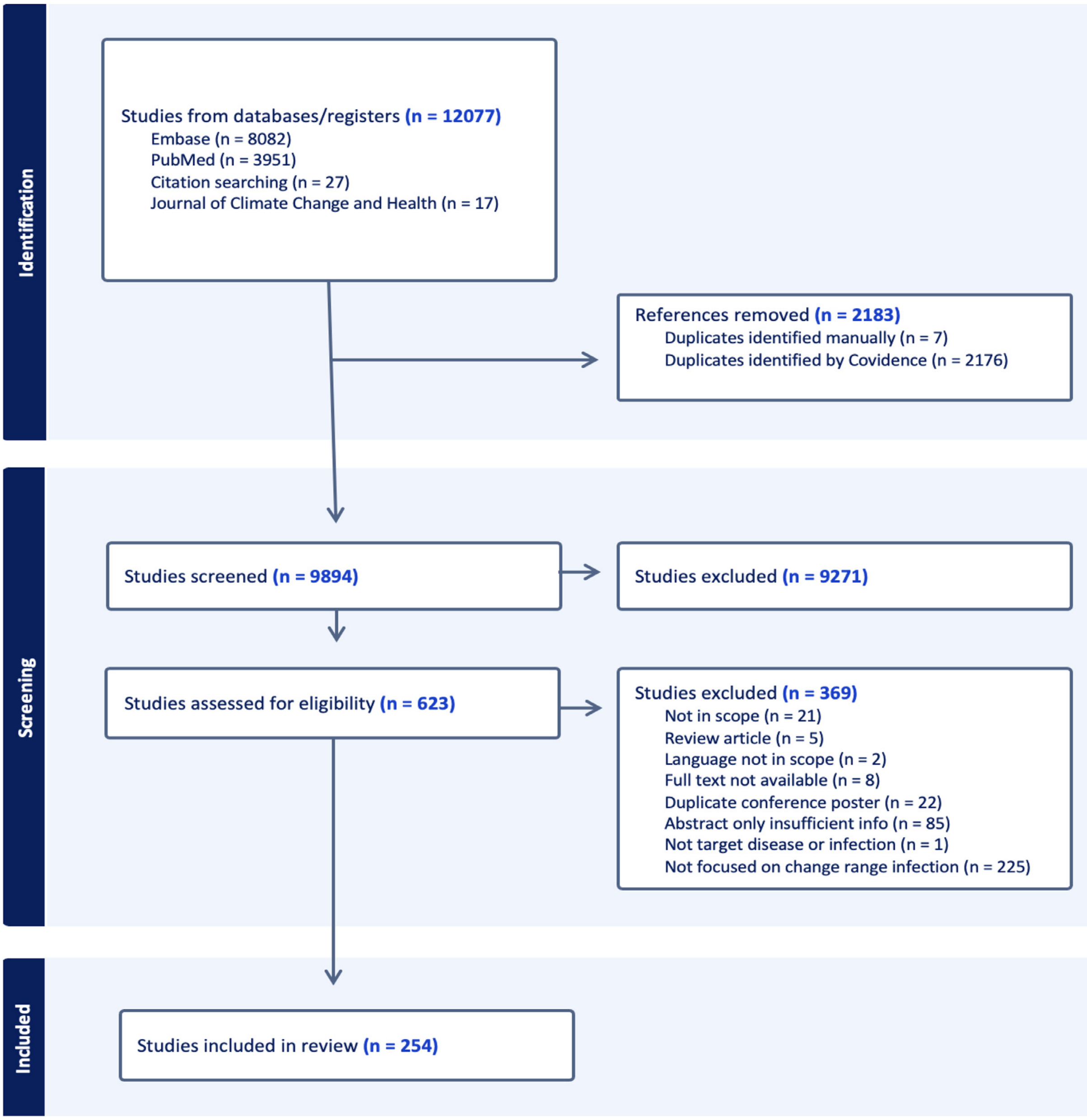

Fig. 1. PRISMA flow diagram of selection of studies for inclusion in the scoping review.

diseases found that individuals living in areas with the highest heat vulnerability index had 1.64 times greater odds of 4 or more hospitalizations [87]. Three studies, including the Nurses' Health Study cohort and the NHANES database, showed no clear association of UV exposure with RA [52-54].

3.1.2. Systemic lupus erythematosus

3.1.2.4. Pollution. Twelve studies reported positive associations between pollution (short- and long-term exposure) and SLE. In terms of short-term pollutant exposure, an evaluation of 237 SLE patients in Montreal showed that short term variations in PM2.5 levels were associated with disease activity as reflected by anti-dsDNA levels and cellular casts [60]. A large multicenter database with 8552 SLE patients in China found that PM2.5 and NO2 were risk factors for lupus nephritis within one month after exposure [58]. Long-term pollutant exposure demonstrated an exposure-response association with CO, NO2 and PM2.5 [59]. Several studies showed a positive association of pollutants with risk for SLE hospitalization [55,56,62,63,65]. One study found a positive association of SLE hospitalizations not only with NOx pollution in the air, but also in water, when studying districts with concentrated chemical industry emission areas [56]. Another study did not find an association between ANA positivity and the pollutants NO2, PM2.5 or O3 using Bayesian Kernal machine regression, however notably these ANA positive subjects did not have a known diagnosis of SLE [72].

3.1.2.5. UV exposure and temperature. Ultraviolet radiation exposure has been associated with flares of SLE symptoms, in particular photosensitive rashes in patients with acute or subacute cutaneous lupus [171,172]. However, risk for the development of SLE due to UV exposure has been less well characterized. In a case control study of 258 SLE patients, an association was seen with outdoor work in the 12 months preceding the diagnosis of SLE (OR 2.0; 95 % CI 1.1, 3.8) with the strongest effect observed in those who reported a blistering sunburn or rash following exposure to midday sun (OR 7.9; 95 % CI 0.97, 64.7) [69]. The Nurses' Health Study looked at 6,054,665 person-years of UV exposure and identified 297 incident SLE cases. They found that

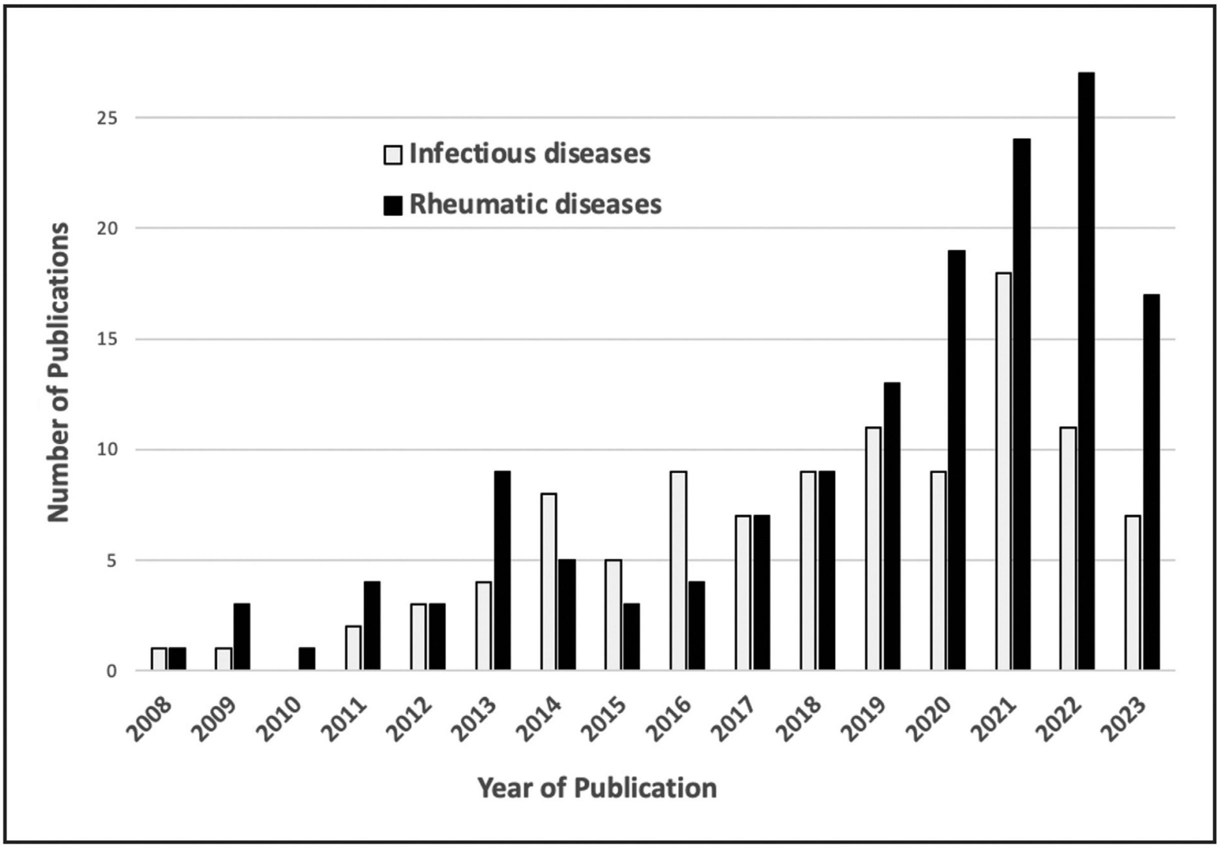

Fig. 2. Number of publications over time on the impact of climate change or related exposures on rheumatic diseases or infectious diseases with arthritogenic manifestations.

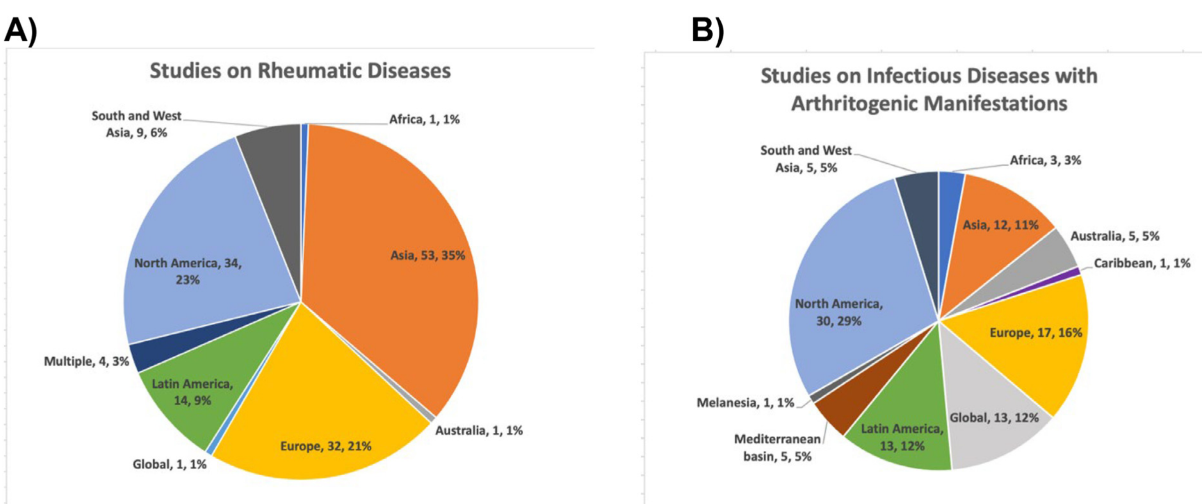

Fig. 3. Geographical locations of the research studies on rheumatic diseases (A) and infectious diseases with arthritogenic manifestations (B) with number of studies and percentage of regions.

women in the highest tercile of UV exposure had an increased risk of malar rash (HR 1.62 [95 % CI 1.04−2.52]); however the risk of overall SLE was not significantly increased when comparing the highest to lowest UV exposure tercile [70]. A study conducted in Southern France showed strong positive correlations between lupus flares and maximum temperature increase, with most lupus flares occurring in the spring season [71]. However, other studies did not find this same association [73-75].

3.1.2.6. Malnutrition. The prognostic nutritional index (PNI) and nutritional risk index (NRI) are useful as screening tools for patient prognosis in several diseases. The PNI and NRI were significantly lower in patients with active vs. inactive SLE ($p < 0.001$ and $p = 0.012$, respectively) suggesting that nutrition status can impact SLE disease activity [67]. The prevalence of obesity is rising and may be associated with nutrient deficiencies that could contribute to inflammation. In a cross-sectional study of 130 SLE patients, patients with excess

Table 3
Change in rheumatic disease activity from climate change related exposures.

Climate exposure	Total # studies	Disease activity or incidence (# studies)		
		Increased	Unchanged	Decreased
Air pollution	87	74	12	1
Malnutrition	21	21	0	0
Temperature	13	10	3	0
UV light	9	6	1	2
UV light and temperature	6	2	3	1
Air pollution and temperature	3	3	0	0
Weather system changes*	2	2	0	0
Precipitation	1	1	0	0
Climate change	0	0	0	0
Total **	**142**	**119 (84 %)**	**19 (13 %)**	**4 (3 %)**

* El Nino Southern Oscillation.
** In 7 studies, disease activity or incidence could not be determined.

weight (BMI > 25 kg/m2) demonstrated a higher clinical activity score using the Mexican SLEDAI (Mex-SLEDAI) [68].

3.1.3. *Kawasaki disease*

Kawasaki disease is a multi-system vasculitis that predominantly occurs in infants and young children and is thought to have an environmental trigger. For example, a consistent pattern of large-scale wind currents originating in central Asia and traveling across the North Pacific seemed to be temporally associated with new hospital admissions of KD cases [100]. An increased occurrence of KD was identified during months with warmer night-time temperatures which in turn correlates with southerly and south-westerly winds [102]. Six studies suggested a possible relationship of KD with prenatal and postnatal exposure to several different pollutants. Only 3 studies failed to establish any correlation between pollutants and KD when examining the short-term exposure of patients to fine particulate matter [103,97,102].

3.1.4. *Systemic sclerosis*

Two studies explored the correlation between environmental pollution and SSc disease severity. One study suggested the possibility of

Table 4
Impact of climate factors on rheumatic diseases.

Rheumatic disease	Total # studies [Ref #]	Disease activity or incidence (# studies)		
		Increased by factor	Unchanged by factor	Decreased by factor
Rheumatoid arthritis (RA)	36 [19-54]*	Air pollution: 17 Malnutrition: 6 Temperature: 3 Precipitation: 1	Air pollution: 4 UV light: 1 UV light and temperature: 1	UV light: 1
Systemic lupus erythematosus (SLE)	21 [55-75]	Air pollution: 11 Malnutrition: 2 UV light 2: Air pollution and temperature: 1 UV light and temperature: 1	UV light and temperature: 2 Air pollution: 1	UV light and temperature: 1
Multiple diseases**	16 [76-91]*	Air pollution: 10 Temperature: 2 Air pollution and temperature: 1	Air pollution: 2	
Kawasaki	12 [92-103]	Air pollution: 5 Weather systems: 2 Air pollution and temperature: 1 Temperature: 1	Air pollution: 3	
Scleroderma	12 [104-115]*	Malnutrition: 9 Air pollution: 1	Air pollution: 1	
Sjogren's	7 [116-122]	Air pollution: 6 UV light and temperature: 1		
Myositis	6 [123-128]	Air pollution: 3 UV light: 3		
Spondyloarthropathy (SpA)	5 [129-133]*	Air pollution: 3 Temperature: 1		
Gout	5 [134-138]	Air pollution: 3 Temperature: 2		
Osteoarthritis (OA)	4 [139-142]	Air pollution: 2	Temperature: 2	
Childhood lupus	4 [143-146]	Air pollution: 4		
CTD related ILD#	4 [147-150]	Air pollution: 3		Air pollution: 1
Juvenile inflammatory arthritis (JIA)	3 [151-153]	Air pollution: 2	Air pollution: 1	
Behcets	3 [154-156]*	Malnutrition: 2		
Others***	11 [157-167]*	Air pollution: 4 Malnutrition: 2 Temperature: 1 UV light: 1	Temperature: 1	UV light: 1

* Includes studies in which disease activity or incidence could not be determined.
** Multiple diseases include: RA (9), SLE (8), scleroderma (6), SpA (6), Sjogren (5), myositis (5), OA (5), UCTD (3), vasculitis (1), gout (1).
# Connective tissue disease (CTD) related interstitial lung disease (ILD).
*** Others: fibromyalgia (3), arthritis (2), pediatric CTD (2), vasculitis (2) CTD (1), sarcoid (1).

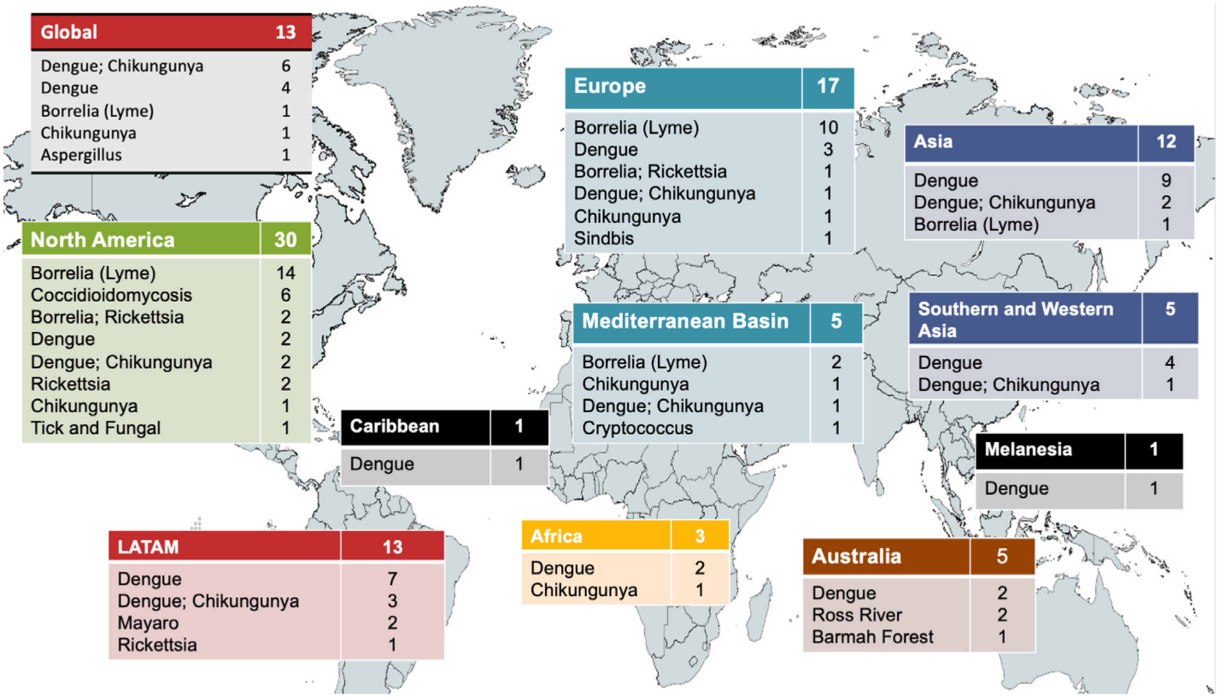

Fig. 4. Number of studies showing infectious diseases with arthritogenic manifestations with a change in range by geographic region. LATAM=Latin America.

adverse disease progression and lung involvement of patients with SSc on exposure to benzene [115], while another described more severe internal organ involvement on exposure to particulate matter [104].

Nine studies investigating the relationship between malnutrition and SSc detected a significant association between malnutrition and systemic involvement including skin, pulmonary and gastrointestinal manifestations. Significantly lower bone density was also noted among patients with SSc having malnutrition [108]. In another study, high nutritional risk detected by the Malnutrition Universal Screening Tool (MUST) was demonstrated to predict mortality among patients with SSc [105].

3.1.5. Sjogren's

A time-series study conducted in Hefei, China showed significant associations between extreme environmental exposures (i.e., long sunshine days, extreme cold, and high humidity) with an increase in outpatient visits for Sjogren's [122]. Six other studies showed positive correlations between air pollution and Sjogren's. In particular, two studies showed correlations between air pollution and ocular surface damage [116] or tear lipid layer thickness [120]. Additional studies reported that exposure to CO, NO and CH_4 were associated with a higher risk of incident Sjogren's, PM2.5, PM10, NO_2, and CO correlated with an elevated risk of hospitalizations [117,118], and PM2.5 and NO_2 were associated with increased risk for outpatient visits [119].

3.1.6. Other diseases

3.1.6.7. Connective tissue disease-associated ILD (CTD-ILD). Four studies investigated the impact of air pollution on CTD-ILD. One found that among patients with RA, there was a higher risk of the development of RA-ILD in those with higher levels of exposure to PM2.5 [147]. Another demonstrated a higher rate of hospitalization for RA-ILD with higher levels of exposure to PM2.5, PM10, SO_2, and NO_2 [149]. Among patients with SSc-ILD, high levels of exposure to O_3 were associated with more severe ILD at diagnosis as well as progression at 24 months [148]. However, a review of patients with several rheumatic conditions (SLE, RA, SSc, dermatomyositis/polymyositis) found a decreased risk of development of ILD with higher exposure to O_3 in patients with SLE [150].

3.1.6.8. Spondyloarthritis. Spondyloarthritis encompasses a group of diagnoses that includes ankylosing spondylitis, psoriasis and psoriatic arthritis, reactive arthritis, and inflammatory bowel-disease related arthritis. In two studies, exposure to air pollution (specifically PM2.5 and CO) was associated with higher disease activity of ankylosing spondylitis [130,131]. Another study found that psoriasis patients had more flares in their skin disease when exposed to higher levels of air pollution before their clinical visits [129]. Two studies also suggested that malnutrition (in the form of high fat diet or nutritional deficiencies) may play a role in SpA disease activity [131,133].

3.1.6.9. Gout. Three studies found that air pollution was associated with an increased incidence of gout and/or gout flares [134-136]. Two studies found that higher temperature was associated with a higher risk of developing a gout attack [137,138].

3.1.6.10. Childhood lupus. There were four studies, all based out of Brazil, that assessed the relationship between disease activity of childhood lupus (clinical organ involvement and/or serologic markers) and air pollution exposure. Higher exposures to PM10, NO_2, and CO were associated with higher lupus disease activity (SLEDAI-2 K) [143] and increased PM2.5 and NO_2 exposure was associated with higher markers of renal disease [144].

3.2. Infectious diseases with arthritogenic manifestations

One hundred and five studies were identified that addressed the influence of climate change on the observed or projected change in the geographical range of diseases with arthritogenic manifestations spread by arthropods or environmental vectors [173-277]. The studies were distributed throughout the world (Fig. 4), though the spectrum of diseases encountered in each region varied considerably. Most of the studies tracked temperature and precipitation due to climate change as the primary variables. The focus was on changes in

Table 5
Infectious diseases with arthritogenic manifestations with changes in the geographical range.

Infection	Total # studies [Ref #]	Change in geographical range (# studies)		
		Increased	Variable or unchanged	Decreased
Dengue	35 [173-207]	32	3	0
Borrelia (Lyme disease)	28 [208-235]	19	9	0
Dengue and Chikungunya	16 [236-251]	8	8	0
Coccidioidomycosis	6 [252-257]	6	0	0
Chikungunya	5 [258-262]	4	1	0
Rickettsia (RMSF)	3 [263-265]	1	1	1
Others*	12 [266-277]	7	5	0
Total	**105**	**77**	**27**	**1**

*Others includes Aspergillus (1), Mayaro virus (2), Sindbis virus (1), Ross River virus (2), Barmah Forest virus (1), Borrelia and Rickettsia (3), Cryptococcus (1), Tick/fungal (1). No studies were identified regarding Semliki virus, O'nyong nyong virus, or Histoplasmosis.

the expected ranges of these diseases since rheumatologists need to be concerned about new or increased risks of infection in their region of practice.

The majority of studies focused on dengue, Lyme disease and chikungunya. An increase in the geographical range with climate change was found with most infections (Table 5). A detailed listing of the papers can be found in Appendix C. Some of the key studies that illustrate the changes in range are discussed below.

3.2.1. Dengue

Dengue, the most common infection noted in the papers that were reviewed, is transmitted between humans by female *Aedes* mosquitoes which are projected to expand in range to more temperate areas and higher altitudes with warming global temperatures. One study estimated the global population at risk for dengue could expand by 1.6 billion by 2070 using more severe climate scenarios [189]. As noted in Fig. 4, every geographical region in this review included studies on dengue, with an increased range noted in 31 of 34 papers. At particular risk of range expansion will be the temperate areas of North America and Europe [189,186].

3.2.2. Borrelia (Lyme disease)

Lyme disease is caused by *Borrelia burgdorferi* and transmitted to humans by ixodid ticks. Although tick survival depends on several factors, temperature is a key determinant of the survival of ixodid populations [219]. Twenty of twenty-nine modeling studies projected an increase in suitable areas for ixodid ticks with climate change, particularly in North America and Europe [231,221,229].

3.2.3. Coccidioidomycosis

Coccidioidomycosis (Valley fever) is a fungal disease that is endemic to the southwestern United States and parts of Central and South America. Human illness is contracted by inhaling fungal spores. The growth cycles of *Coccidioides* spp. are driven by a complex balance of temperature and precipitation [252]. The six studies in this review, all from North America, predicted a marked increase in the expected range of coccidioidomycosis in the western United States with climate model projections.

3.2.4. Chikungunya

Chikungunya is a mosquito-borne arboviral disease transmitted by *Aedes* species mosquitoes. Historically confined to tropical settings, it can spread to other regions with favorable combinations of temperature and rainfall. Studies regarding chikungunya, often in combination with dengue, were found in most regions of the world. Many of the studies project a spread in its geographical range with future climate scenarios, particularly to China, sub-Saharan Africa, South America, the United States, and continental Europe [258-260]. However, nine of the twenty-one studies including chikungunya noted variable changes in range, since climate change is expected to increase temperatures beyond the suitable range for transmission in many parts of the world [247,246].

3.2.5. Rickettsia (RMSF)

Rocky Mountain spotted fever (RMSF) is a life−threatening fulminant tick-borne infection caused by *Rickettsia rickettsii*. Projecting climate induced changes in the geographical distribution of RMSF is complex, since its propagation is also impacted by land cover, landscape structure and socio−economic factors [264]. Of the six studies found in the review, 2 projected an increased range and 3 noted variable changes. A study in Brazil estimated a reduction of areas suitable for ticks of the *Amblyomma cajennense* species complex, vectors for spotted fever, due to excess heat [263].

3.2.6. Other infections

Nine studies investigated various other infections, including aspergillus, Mayaro virus, Sindbis virus, Ross River virus, Barmah Forest virus and cryptococcus. Six papers showed an increase in projected range with climate change, while 3 showed variable changes. Of note, no studies were identified that described changes in geographical range with climate change for Semliki Forest virus, O'nyong nyong virus or histoplasmosis.

3.3. Gray literature search

In the search of the websites of seven major rheumatology associations, a few contained information about climate change (Table 6). Two notable findings were a plan for a sustainable annual conference by the British Society for Rheumatology and a well-organized and extensive position statement by the Australian Rheumatology Association.

4. Discussion

Rheumatic diseases are chronic conditions affecting a growing number of individuals worldwide, with significant impacts on

Table 6
Review of climate change issues on rheumatology organization websites (accessed September 2023).

Organization	Climate change text word search	Climate change content in articles, position statements, podcasts, newsletters
American College of Rheumatology	• 2 climate presentations at 2022 ACR Convergence meeting	• 1 podcast on environmental impacts on rheumatic diseases • 2 news articles on the impact of storms • 1 news article on chikungunya
Canadian Rheumatology Association)	• 1 article on a scientist active on climate issues	• N/A
British Society for Rheumatology	• N/A	• Comprehensive sustainability plan for 2023 annual conference
European Alliance of Associations for Rheumatology	• N/A	• N/A
Asia Pacific League of Associations for Rheumatology	• N/A	• N/A
African League of Association for Rheumatology	• N/A	• N/A
Australian Rheumatology Association	• 60 results on climate change issues	• Comprehensive position statement

morbidity and mortality, and with substantial costs to society [8,278,279]. It is estimated that 1 in 10 citizens in the UK has an autoimmune condition [280]. In addition, it is well documented that significant health disparities occur, particularly in diseases such as SLE [281]. Based on findings from this scoping review, climate change may increase known exposures associated with triggering autoimmunity, leading to increases in the incidence and severity of several rheumatic conditions, as well as drive an increased range of infections with arthritogenic manifestations. These effects will likely be more pronounced in socially vulnerable groups. There is a lack of research data linking the effects of climate change mechanistically to specific rheumatic or immunologic disease processes, and further investigation is needed.

Autoimmunity has an insidious onset, with complex and multistep pathogenesis involving the interplay of genetic predisposition, epigenetic changes, environmental exposures, infections and alterations in the microbiome. Furthermore, socioeconomic factors have been closely associated with rheumatic disease severity, such as poverty, poor access to health care, and race/ethnicity, leading to disease initiation and perpetuation [282-287]. As this scoping review does not comprehensively address the interaction between these factors and all the potential impacts of climate change in rheumatology, we assert that there are many remaining gaps to be filled. As social disparities are increasing as a direct result of climate change, many more rheumatic patients with high social vulnerability stand to be adversely impacted [87].

4.1. Impacts of climate change factors on rheumatic diseases

An initial attempt to capture the themes of climate change and its direct impacts (i.e. extreme weather events) across a wide variety of rheumatic diseases yielded minimal publications. By expanding the search to include terms capturing air pollution (driven mostly by fossil fuels which cause climate change), malnutrition (an anticipated consequence of climate change), temperature changes (but not necessarily extreme heat), and UV radiation, 149 studies were identified. This review primarily focuses on indirect climate change factors. These findings are consistent with a recent scoping review, stating that air pollution and changes in temperature were the most extensively investigated climate change factors [288]. Respiratory and cardiovascular diseases were the best represented medical conditions in the literature, perhaps given more direct and obvious mechanistic links of these climate change factors to disease pathogenesis [288].

Findings from this scoping review primarily encompassed the role of air pollutants (90 out of 142 studies, 63 %), with the vast majority showing an increase in rheumatic disease incidence and severity. Air pollution can induce systemic inflammatory responses via a variety of mechanisms [289] and has even been identified as a potential risk factor for the development of rheumatic disease [290]. There was a preponderance of studies from Asia on air pollution (39 out of 52, 75 %). Of note, the WHO global air quality guidelines from 2021 state that the limits for PM2.5 and PM10 are 15 ug/m^3 and 45 ug/m^3, whereas the limits in China are notably higher at 35 ug/m^3 and 50 ug/m^3, respectively [291]. Air pollution caused by heavy industry and mining are likely driving more severe rheumatic disease impacts in Asia.

Many studies on temperature fluctuations were associated with disease worsening; however, a few studies cited improved arthritis symptoms with warmer weather. A notable gap is that none of the studies specifically evaluated the impacts of extreme heat or extreme cold. In addition, outcomes were primarily focused on rheumatic disease activity (i.e. joint inflammation, serologies). However, given the high incidence of comorbidities in these patients [292], such as cardiovascular disease, which is known to increase susceptibility to extreme heat, the impact of temperature extremes should be further investigated in rheumatic patients [293].

Malnutrition as a general theme, but not specifically resulting from climate change, was interrogated in this scoping review. It is well accepted that climate change is projected to increase malnutrition and food insecurity via extreme weather events, drought, changes in soil fertility, decreasing crop yields, and decreasing bioavailability of nutrients in foods [294]. All studies on malnutrition unanimously reported worsening rheumatic disease measures, which highlights a health risk for which rheumatologists should be prepared.

4.2. Impacts of climate change factors on infectious diseases with arthritogenic manifestations

There is a robust body of literature addressing the increasing geographic footprint and extended seasonality of several infectious diseases due to climate change, especially those that are vector-borne [11,295]. To better prepare rheumatologists for what to anticipate in different regions of the world, the focus was on infections with arthritogenic manifestations that demonstrated evolving geographic ranges in the context of climate-related exposures. The majority of studies on arthritogenic infections demonstrated an increase in range, less frequently a variable change in range, and with only one study demonstrating a decrease in range. These infections will pose a diagnostic challenge for rheumatologists as they try to differentiate a flare of inflammatory arthritis from infectious arthritis. This is further complicated by the fact that many patients are treated with immunosuppression, rendering them more susceptible to infectious insults. An additional consideration is that in up to 40 % of patients, the chikungunya virus can cause a chronic arthritis that resembles RA and is treated with similar disease modifying anti-rheumatic agents such as methotrexate [296]. Lyme disease, anticipated to expand in geographic range and seasonality, is a well-known trigger of a post-infectious arthritis which can in some cases become chronic, with synovial pathology that is similar to RA [297]. Another study found that a history of dengue infection was significantly associated with SLE [298]. Taken together, these studies raise the concerning possibility that increases in several infectious diseases driven by climate change may in fact catalyze the onset or exacerbation of rheumatic diseases.

4.3. Knowledge gaps

There are a myriad of possible mechanisms by which climate change can impact rheumatic diseases, and the current literature only begins to dissect these possibilities. For example, there is a substantial body of literature on the role of stress leading to exacerbation of rheumatic diseases via cortisol and other inflammatory cytokines [299]. “Eco-anxiety” is a term that has been recently coined to describe anxiety related to anticipation of the negative downstream impacts from climate change [300]. Displacement due to climate related disasters and food insecurity will certainly lead to increased anxiety and stress. This study did not specifically interrogate the role of climate-related stress but substantial negative consequences for our rheumatic patients could be anticipated.

The direct impacts of climate change (i.e., extreme weather events) on rheumatic diseases need further exploration. Climate change will lead to more extreme weather, including temperature and precipitation shifts and worsened air quality that will make outdoor exercise less feasible. Inactivity will lead to deconditioning and associated conditions such as obesity, which is known to exacerbate inflammation in rheumatic diseases [301]. Wildfires threatening air quality will have disproportionate impacts on patients with ILD, including ILD patients with SSc, myositis, RA, and Sjogren’s, and may lead to more disease flares. Climate change can affect water sanitation which could increase enteric infections that drive complications such as reactive arthritis. A rise in the frequency of infections due to climate change should be tracked to see if they trigger an initiation or flare of autoimmune diseases [302].

There was a notable disparity in the numbers of publications from low-income countries, which are anticipated to be most heavily affected by climate change. This dearth of publications may be multifactorial, perhaps related to limited access to medical literature, lack of resources (including high publication costs), and competing work demands.

4.4. Limitations

There were several limitations of this scoping review. The limitation to papers written in the English language could have introduced bias. For example, excluding non-English studies may limit the generalizability of findings to populations in non-English-speaking regions, where the prevalence or impact of autoimmune rheumatic diseases may differ. In addition, we only searched 2 major databases, did a targeted search of the *Journal of Climate Change and Health* in Scopus, performed a limited gray literature search, and excluded reviews, editorials, and conference abstracts such that some relevant publications may have been missed. A risk of bias assessment was not performed in this scoping review.

The identified studies predominantly focus on associations between indirect climate-related exposures and rheumatic diseases, with limited exploration of causal relationships or underlying mechanisms. This limitation hinders a deeper understanding of how climate change directly influences the pathophysiology of rheumatic diseases, thereby constraining the ability to develop effective preventive and management strategies.

Most studies included in the review primarily address the impact of indirect climate change exposures on rheumatic diseases in terms of disease activity or incidence, neglecting other critical aspects such as treatment responses, disease progression, and patient outcomes. This narrow focus may overlook potential nuances in the relationship between climate change and rheumatic diseases, thereby limiting the comprehensiveness of the findings.

4.5. Future directions

Based on results from this scoping review, it is undeniable that climate change is currently affecting and will continue to adversely affect patients with rheumatic diseases. Future studies should aim to elucidate the underlying mechanisms through which climate-related factors influence the pathophysiology of rheumatic diseases. This requires interdisciplinary collaboration between rheumatologists, climatologists, and other relevant experts to explore the complex interactions between environmental exposures, immune responses, and genetic predispositions. Additionally, there is a need for longitudinal studies to assess the long-term effects of climate change on rheumatic disease outcomes, including disease progression, treatment responses, and patient quality of life. Longitudinal data collection will provide valuable insights into the evolving nature of rheumatic diseases in the context of changing climate patterns, facilitating the development of targeted interventions and personalized treatment strategies.

Future research should expand beyond the commonly studied rheumatic diseases such as RA and SLE to include other less well-characterized conditions such as KD and SSc. This broader focus will help identify specific vulnerabilities and susceptibilities within diverse patient populations, enabling more tailored approaches to prevention, diagnosis, and management.

The accelerating climate emergency is leading to a multitude of health harms, disproportionately impacting lower income countries and more vulnerable populations. Moving forward it will be critical to employ modern mapping data to better define high risk populations that are vulnerable to specific climate effect risks in order to devise adaptation strategies to limit harm.

The rheumatology community has only begun to define the mechanisms by which climate change is threatening human health and well-being. To date, only the Australian Rheumatology Society has issued a position statement on climate change, whereas most other rheumatology organizations have remained silent on this issue. Medical organizations can be powerful agents of change through advocacy, education, and research. It is incumbent upon rheumatologists to be aware of the health hazards resulting from climate change and to consider how these hazards may be impacting our rheumatic patients. Importantly, we must continue to perform research in these domains, educate our colleagues and patients on these climate impacts, and advocate for policies to proactively address the climate crisis.

Author agreement

The authors agree to terms and conditions of the publication.

Funding support

TRK receives research support from Sanofi. TF receives research support from NIH K01-AR-079039 from NIAMS.

Ethical approval

not applicable

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Tamiko R. Katsumoto reports financial support was provided by Sanofi. Titilola Falasinnu reports financial support was provided by National Institute of Arthritis and Musculoskeletal and Skin Diseases. Tamiko R. Katsumoto reports a relationship with Genentech Inc that includes: consulting or advisory. Tamiko R. Katsumoto reports a relationship with Sonoma Biotherapeutics that includes: consulting or advisory. Tamiko R. Katsumoto reports a relationship with Sanofi that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Tamiko R. Katsumoto: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Liya Stolyar:** Writing – review & editing, Formal analysis, Data curation. **Chathurika L. Dandeniya:** Writing – review & editing, Formal analysis, Data curation. **Hong Nei Wong:** Methodology, Data curation. **Cristina M. Lanata:** Writing – review & editing. **Titilola Falasinnu:** Writing – review & editing. **Thomas Bush:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.joclim.2024.100338.

References

[1] Romanello M, Napoli CD, Green C, Kennard H, Lampard P, Scamman D, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. Lancet 2023;S0140-6736(23) 01859-7. doi: 10.1016/S0140-6736(23)01859-7.

[2] New York Times. See how 2023 shattered records to become the hottest year. Accessed at https://www.nytimes.com/2024/01/09/climate/2023-warmest-year-record.html on February 17, 2024

[3] Patz JA, Gibbs HK, Foley JA, Rogers JV, Smith KR. Climate change and global health: quantifying a growing ethical crisis. Ecohealth 2017;4:397–405. doi: 10.1007/s10393-007-0141-1.

[4] World Health Organization. Fact sheet: climate change and health, 2018. Accessed at https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health on February 17, 2024.

[5] McMichael A., Campbell-Lendrum D., Kovats S., Edwards S., Wilkinson P., Wilson T., et al. Global climate change. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, editors. Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors. Geneva, Switzerland: World Health Organization; 2014. p. 1543–649.

[6] IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An ipcc special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Masson-Delmotte VP, Zhai HO, Pörtner D, Roberts D, Skea J, Shukla PR,et al. https://www.ipcc.ch/sr15/chapter/spm/

[7] Bush T. Potential adverse health consequences of climate change related to rheumatic diseases. J Clim Chang Heath 2021;3:100029 article. doi: 10.1016/j.joclim.2021.100029.

[8] Dinse GE, Parks CG, Weinberg CR, Co CA, Wilkerson J, Zeldin DC, et al. Increasing Prevalence of Antinuclear Antibodies in the United States. Arthritis Rheumatol 2022;74:2032–41 Epub 2022 Oct 19. PMID: 36054084. doi: 10.1002/art.42330.

[9] Miller FW. The increasing prevalence of autoimmunity and autoimmune diseases: an urgent call to action for improved understanding, diagnosis, treatment, and prevention. Curr Opin Immunol 2023;80:102266. doi: 10.1016/j.coi.2022.102266.

[10] Dellaripa PF, Bush T, Miller FW, Feldman CH. The Climate Emergency and the Health of Our Patients: the Role of the Rheumatologist. Arthritis Rheumatol 2023;75:1–3. doi: 10.1002/art.42279.

[11] Baker RE, Mahmud AS, Miller IF, Rajeev M, Rasambainarivo F, Rice BL, et al. Infectious disease in an era of global change. Nat Rev Microbiol 2022;20:193–205. doi: 10.1038/s41579-021-00639-z.

[12] Page MJ, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C, et al. The PRISMA 2020 Statement: an Updated Guideline for Reporting Systematic Reviews. MetaArXiv 2020. doi: 10.1016/j.ijsu.2021.105906.

[13] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med 2018;169:467–73. doi: 10.7326/M18-0850.

[14] Herrero LJ, Taylor A, Wolf S, Mahalingam S. Arthropod-borne arthritides. Best Pract Res Clin Rheumatol 2015;29:259–74. doi: 10.1016/j.berh.2015.04.003.

[15] Suchowiecki K, Reid SP, Simon GL, Firestein GS, Chang A. Persistent joint pain following arthropod virus infections. Curr Rheumatol Rep 2021;23:26. doi: 10.1007/s11926-021-00987-y.

[16] Olivia LW, Obanda V, Bucht G, Mosomtai G, Otieno V, Ahlm C, et al. Global emergence of *Alphaviruses* that cause arthritis in humans. Infection Ecology Epidemiology 2015;5:1. doi: 10.3402/iee.v5.29853.

[17] United Nations Sustainable Development Goals. Accessed at https://unstats.un.org/unsd/methodology/m49/on October 1, 2023.

[18] European Environment Agency. Mediterranean Sea region briefing - The European environment — State and outlook 2015. Accessed at https://www.eea.europa.eu/soer/2015/countries/mediterranean on February 20, 2024.

[19] Hart JE, Laden F, Puett RC, Costenbader KH, Karlson EW. Exposure to traffic pollution and increased risk of rheumatoid arthritis. Environ Health Perspect 2009;117:1065–9. doi: 10.1289/ehp.0800503.

[20] Li J, Li X, Xia Y, Fan H, Fan D, Xi X, et al. Subgroup analysis of the relationship between polycyclic aromatic hydrocarbons and rheumatoid arthritis: data from the National Health and Nutrition Examination Survey, 2003–2014. Sci Total Environ 2021;775:145841. doi: 10.1016/j.scitotenv.2021.145841.

[21] Jung CR, Hsieh HY, Hwang BF. Air pollution as a potential determinant of rheumatoid arthritis: a population-based cohort study in Taiwan. Epidemiology 2017;28(Suppl 1):S54–9. doi: 10.1097/EDE.0000000000000732.

[22] Alsaber A, Pan J, Al-Herz A, Alkandary DS, Al-Hurban A, Setiya P, et al. Influence of Ambient Air Pollution on Rheumatoid Arthritis Disease Activity Score Index. Int J Environ Res Public Health 2020;17(2). doi: 10.3390/ijerph17020416.

[23] Shin J, Lee J, Ha EH. Association between exposure to ambient air pollution and rheumatoid arthritis in adults. Int J Environ Res Public Health 2019;16(7). doi: 10.3390/ijerph16071227.

[24] Chen H, Wu J, Wang M, Wang J, Yu H, Hu Y, et al. Association between ambient fine particulate matter and adult outpatient visits for rheumatoid arthritis in Beijing, China. Int J Biometeorol 2023;67(1):149–56. doi: 10.1007/s00484-022-02393-0.

[25] Chang KH, Hsu CC, Muo CH, Cy Hsu, Liu HC, Kao CH, et al. Air pollution exposure increases the risk of rheumatoid arthritis: a longitudinal and nationwide study. Environ Int 2016;94:495–9. doi: 10.1016/j.envint.2016.06.008.

[26] Zhao N, Smargiassi A, Hatzopoulou M, Colmegna I, Hudson M, Fritzler MJ, et al. Long-term exposure to a mixture of industrial SO(2), NO(2), and PM(2.5) and anti-citrullinated protein antibody positivity. Environ Health 2020;19(1):86. doi: 10.1186/s12940-020-00637-3.

[27] Gałuszka-Bulaga A, Hajto J, Borczyk M, Golda S, Piechota M, Korostyriski M, et al. Transcriptional response of blood mononuclear cells from patients with inflammatory and autoimmune disorders exposed to "Krakow Smog. Cells 2022;11 (16):2586. doi: 10.3390/cells11162586.

[28] Zhang J, Fang XY, Wu J, Fan YG, Leng RX, Liu B, et al. Association of combined exposure to ambient air pollutants, genetic risk, and incident rheumatoid arthritis: a prospective cohort study in the UK biobank. Environ Health Perspect 2023;131(3):37008. doi: 10.1289/EHP10710.

[29] Wu Q, Xu Z, Dan YL, Cheng J, Zhao CN, Mao YM, et al. Association between traffic-related air pollution and hospital readmissions for rheumatoid arthritis in Hefei, China: a time-series study. Environ Pollut 2021;268(Pt A):115628. doi: 10.1016/j.envpol.2020.115628.

[30] Adami G, Viapiana O, Rossini M, Orsolini G, Bertoldo E, Giollo A, et al. Association between environmental air pollution and rheumatoid arthritis flares. Rheumatology (Oxford) 2021;60(10):4591–7. doi: 10.1093/rheumatology/keab049.

[31] Alex AM, Kunkel G, Sayles H, Flautero Arcos JD, Mikuls TR, Kerr GS. Exposure to ambient air pollution and autoantibody status in rheumatoid arthritis. Clin Rheumatol 2020;39(3):761–8. doi: 10.1007/s10067-019-04813-w.

[32] De Roos AJ, Koehoorn M, Tamburic L, Davies HW, Brauer M. Proximity to traffic, ambient air pollution, and community noise in relation to incident rheumatoid arthritis. Environ Health Perspect 2014;122(10):1075–80. doi: 10.1289/ehp.1307413.

[33] Ho WC, Chou LW, Wang RY, Doan TN, Yu HL, Chou TH, et al. Association between exposure to ambient air pollution and the risk of rheumatoid arthritis in taiwan: a population-based retrospective cohort study. Int J Environ Res Public Health 2022;19(12):7006. doi: 10.3390/ijerph19127006.

[34] Bernatsky S, Smargiassi A, Joseph L, Awadalla P, Colmegna I, Hudson M, et al. Industrial air emissions, and proximity to major industrial emitters, are associated with anti-citrullinated protein antibodies. Environ Res 2017;157:60–3. doi: 10.1016/j.envres.2017.04.035.

[35] Zhao N, Smargiassi A, Colmegna I, Hudson M, Fritzler M, Bernatsky S. Sunlight exposure, sun-protective behavior, and anti-citrullinated protein antibody

positivity: a general population-based study in Quebec, Canada. Arthritis Care Res (Hoboken) 2022;74(2):236–42. doi: 10.1002/acr.24448.
[36] Tian P, Xiong J, Wu W, Shi S, Chen A, Chen K, et al. Impact of the malnutrition on mortality in Rheumatoid arthritis patients: a cohort study from NHANES 1999-2014. Front Nutr 2022;9:993061. doi: 10.3389/fnut.2022.993061.
[37] Cai Q, Pesa J, Wang R, Fu AZ. Depression and food insecurity among patients with rheumatoid arthritis in NHANES. BMC Rheumatol 2022;6(1):6. doi: 10.1186/s41927-021-00236-w.
[38] Doubek JGC, Kahlow BS, Nisihara R, Skare TL. Rheumatoid arthritis and nutritional profile: a study in Brazilian females. Int J Rheum Dis 2022;25(10):1145–51. doi: 10.1111/1756-185X.14394.
[39] Mochizuki T, Yano K, Ikari K, Okazaki K. Factors associated with nutrition of japanese patients with rheumatoid arthritis who underwent the Mini Nutritional Assessment (MNA), health assessment questionnaire disability index, and body composition assessment by bioelectrical impedance analysis. J Nutr Sci Vitaminol (Tokyo) 2020;66(3):219–23. doi: 10.3177/jnsv.66.219.
[40] Tański W, Wójciga J, Jankowska-Polańska B. Association between malnutrition and quality of life in elderly patients with rheumatoid arthritis. Nutrients 2021;13(4). doi: 10.3390/nu13041259.
[41] Matsumoto Y, Sugioka Y, Tada M, Okano T, Mamoto K, Inui K, et al. Impact of disease burden or inflammation on nutritional assessment by the GLIM criteria in female patients with rheumatoid arthritis. Clin Nutr ESPEN 2022;52:353–9. doi: 10.1016/j.clnesp.2022.09.016.
[42] Işik M, Khan AS, Avşar Ü, Set T, Çayir Y. Climatic effect on rheumatoid arthritis. Turkiye Klinikleri J Med Sci 2013;33(3):746–50. doi: 10.5336/medsci.2012-31125.
[43] Huang LJ, Zha JJ, Cao NW, Zhou HY, Chu XJ, Wang H, et al. Temperature might increase the hospital admission risk for rheumatoid arthritis patients in Anqing, China: a time-series study. Int J Biometeorol 2022;66(1):201–11. doi: 10.1007/s00484-021-02207-9.
[44] Azzouzi H, Ichchou L. Seasonal and weather effects on rheumatoid arthritis: myth or reality? Pain Res Manag 2020;2020:1–5. doi: 10.1155/2020/5763080.
[45] Wang J, Yu L, Deng J, Gao X, Chen Y, Shao M, et al. Short-term effect of meteorological factors on the risk of rheumatoid arthritis hospital admissions: a distributed lag non-linear analysis in Hefei, China. Environ Res 2022;207:112168. doi: 10.1016/j.envres.2021.112168.
[46] Duarte GBS, Callou KRA, Almondes KGS, Rogero MM, Pollak DF, Cozzolino SMF. Evaluation of biomarkers related to zinc nutritional status, antioxidant activity and oxidative stress in rheumatoid arthritis patients. Nutr Health 2022;28(2):257–64. doi: 10.1177/02601060211015594.
[47] Ullah Z, Ullah MI, Hussain S, Kaul H, Lone KP. Determination of serum trace elements (Zn, Cu, and Fe) in Pakistani patients with rheumatoid arthritis. Biol Trace Elem Res 2017;175(1):10–6. doi: 10.1007/s12011-016-0746-8.
[48] Gan RW, Deane KD, Zerbe GO, Demoruelle MK, Weisman MH, Buckner JH, et al. Relationship between air pollution and positivity of RA-related autoantibodies in individuals without established RA: a report on SERA. Ann Rheum Dis 2013;72(12):2002–5. doi: 10.1136/annrheumdis-2012-202949.
[49] Ingegnoli F, Ubiali T, Schioppo T, Longo V, Murgo A, De Lucia O, et al. Potential Short-Term Air Pollution Effects on Rheumatoid Arthritis Activity in Metropolitan Areas in the North of Italy: a Cross-Sectional Study. Int J Environ Res Public Health 2021;8(16). doi: 10.3390/ijerph18168490.
[50] Hart JE, Källberg H, Laden F, Bellander T, Costenbader KH, Holmqvist M, et al. Ambient air pollution exposures and risk of rheumatoid arthritis: results from the Swedish EIRA case-control study. Ann Rheum Dis 2013;72(6):888–94. doi: 10.1136/annrheumdis-2012-201587.
[51] Hart JE, Källberg H, Laden F, Costenbader KH, Yanosky JD, Klareskog L, et al. Ambient air pollution exposures and risk of rheumatoid arthritis. Arthritis Care Res (Hoboken) 2013;65(7):1190–6. doi: 10.1002/acr.21975.
[52] Arkema EV, Hart JE, Bertrand KA, Laden F, Grodstein F, Rosner BA, et al. Exposure to ultraviolet-B and risk of developing rheumatoid arthritis among women in the Nurses' Health Study. Ann Rheum Dis 2013;72(4):506–11. doi: 10.1136/annrheumdis-2012-202302.
[53] Madusor R, Bedaiwi A, Womas K, Pei W. Investigating the relationship between overexposure to ultraviolet radiation and rheumatoid arthritis using national health and nutrition examination survey (NHANES) 2015-2016 data. Cureus 2022;14(8):e28298. doi: 10.7759/cureus.28298.
[54] Smedslund G, Mowinckel P, Heiberg T, Kvien TK, Hagen KB. Does the weather really matter? A cohort study of influences of weather and solar conditions on daily variations of joint pain in patients with rheumatoid arthritis. Arthritis Rheum 2009;61(9):1243–7. doi: 10.1002/art.24729.
[55] Chen P, Huang J, Li S, Tang Y, Xiao Y, Zou B, et al. Nitrogen dioxide and hospital length of stay and cost for systemic lupus erythematosus in Hunan. China. Sci Total Environ 2023;856(Pt 1):159013. doi: 10.1016/j.scitotenv.2022.159013.
[56] Chen J, Qu W, Sun L, Chen J, Kong W, Wang F, et al. The relationship of polluted air and drinking water sources with the prevalence of systemic lupus erythematosus: a provincial population-based study. Sci Rep 2021;11(1):18591. doi: 10.1038/s41598-021-98111-8.
[57] Blaskievicz PH, Silva AMC, Fernandes V, Pinto Jr OB, Shimoya-Bittencourt W, Ferreira SMB, et al. Atmospheric pollution exposure increases disease activity of systemic lupus erythematosus. Int J Environ Res Public Health 2020;17(6). doi: 10.3390/ijerph17061984.
[58] Bai H, Jiang L, Li T, Zuo X, Liu Y, Hu S, et al. Acute effects of air pollution on lupus nephritis in patients with systemic lupus erythematosus: a multicenter panel study in China. Environ Res 2021;195:110875. doi: 10.1016/j.envres.2021.110875.
[59] Jung CR, Chung WT, Chen WT, Lee RY, Hwang BF. Long-term exposure to traffic-related air pollution and systemic lupus erythematosus in Taiwan: a cohort study. Sci Total Environ 2019;668:342–9. doi: 10.1016/j.scitotenv.2019.03.018.
[60] Bernatsky S, Fournier M, Pineau CA, Clarke AE, Vinet E, Smargiassi A. Associations between ambient fine particulate levels and disease activity in patients with systemic lupus erythematosus (SLE). Environ Health Perspect 2011;119(1):45–9. doi: 10.1289/ehp.1002123.
[61] Sahebari M, Rajabi E, Esmaili H, Orooji A, Dowlatabadi Y. Effects of air pollution on disease activity and health-related quality of life of systemic lupus erythematous patients: an iranian observational longitudinal study. Curr Rheumatol Rev 2023;19(2):222–9. doi: 10.2174/1573397118666221011121308.
[62] Cakmak S, Blanco-Vidal C, Lukina AO, Dales R. The association between air pollution and hospitalization for patients with systemic lupus erythematosus in Chile: a daily time series analysis. Environ Res 2021;192:110469. doi: 10.1016/j.envres.2020.110469.
[63] Pan Y, Fang Y, Chen Y, Chen C, Zhang RD, Fang X, et al. Associations between particulate matter air pollutants and hospitalization risk for systemic lupus erythematosus: a time-series study from Xi'an, China. Environ Geochem Health 2023;45(6):3317–30. doi: 10.1007/s10653-022-01409-3.
[64] Chen PY, Tsan YT, Yang CT, Lee YM, Chen LL, Ho WC, et al. Prediction of risk of ischemic heart disease in first-diagnosed systemic lupus erythematosus patients in taiwan: is air pollution exposure a risk factor? BMC Rheumatol 2023;7(1):14. doi: 10.1186/s41927-023-00337-8.
[65] Zhao CN, Mei YJ, Wu GC, Mao YM, Wu Q, Dan YL, et al. Effect of air pollution on hospital admissions for systemic lupus erythematosus in Bengbu, China: a time series study. Lupus 2019;28(13):1541–8. doi: 10.1177/0961203319882503.
[66] Stojan G, Kvit A, Curriero FC, Petri M. A Spatiotemporal analysis of organ-specific lupus flares in relation to atmospheric variables and fine particulate matter pollution. Arthritis Rheumatol 2020;72(7):1134–42. doi: 10.1002/art.41217.
[67] Correa-Rodríguez M, Pocovi-Gerardino G, Callejas-Rubio JL, Fernandez RR, Martin-Amada M, Cruz-Caparros MG, et al. The prognostic nutritional index and nutritional risk index are associated with disease activity in patients with systemic lupus erythematosus. Nutrients 2019;11(3). doi: 10.3390/nu11030638.
[68] Meza-Meza MR, Vizmanos-Lamotte B, Muñoz-Valle JF, Parra-Rojas I, Garaulet M, Campos-Lopez B, et al. Relationship of excess weight with clinical activity and dietary intake deficiencies in systemic lupus erythematosus patients. Nutrients 2019;11(11). doi: 10.3390/nu11112683.
[69] Cooper GS, Wither J, Bernatsky S, Claudio JO, Clarke A, Rioux JD, et al. Occupational and environmental exposures and risk of systemic lupus erythematosus: silica, sunlight, solvents. Rheumatology (Oxford) 2010;49(11):2172–80. doi: 10.1093/rheumatology/keq214.
[70] Barbhaiya M, Hart JE, Malspeis S, Tedeschi SK, VoPham T, Sparks JA, et al. Association of ultraviolet B radiation and risk of systemic lupus erythematosus among women in the nurses' health studies. Arthritis Care Res (Hoboken) 2023;75(7):1409–15. doi: 10.1002/acr.24974.
[71] Chiche L, Jourde N, Ulmann C, Mancini J, Darque A, Bardin N, et al. Seasonal variations of systemic lupus erythematosus flares in southern France. Eur J Intern Med 2012;23(3):250–4. doi: 10.1016/j.ejim.2011.12.006.
[72] Zhao N, Smargiassi A, Hudson M, Fritzler MJ, Bernatsky S. Investigating associations between anti-nuclear antibody positivity and combined long-term exposures to NO(2), O(3), and PM(2.5) using a Bayesian kernel machine regression approach. Environ Int 2020;136:105472. doi: 10.1016/j.envint.2020.105472.
[73] Zhang T, Xie Q, Wang L, Wang Y, Yan Z, Li Z, et al. Impact of climate factors and climate−gene interaction on systemic lupus erythematosus patients' response to glucocorticoids therapy. Clin Lab Anal 2023;37(13−14):e24945. doi: 10.1002/jcla.24945.
[74] Duarte-Garcia A, Fang H, To CH, Magder LS, Petri M. Seasonal variation in the activity of systemic lupus erythematosus. J Rheumatol 2012;39(7):1392–8. doi: 10.3899/jrheum.111196.
[75] Hua-Li Z, Shi-Chao X, De-Shen T, Dong L, Hua-Feng L. Seasonal distribution of active systemic lupus erythematosus and its correlation with meteorological factors. Clinics (Sao Paulo) 2011;66(6):1009–13. doi: 10.1590/s1807-59322011000600015.
[76] Shepherd A, Mullins JT. Arthritis diagnosis and early-life exposure to air pollution. Environ Pollut 2019;253:1030–7. doi: 10.1016/j.envpol.2019.07.054.
[77] Bernatsky S, Smargiassi A, Barnabe C, Svenson LW, Brand A, Martin RV, et al. Fine particulate air pollution and systemic autoimmune rheumatic disease in two Canadian provinces. Environ Res 2016;146:85–91. doi: 10.1016/j.envres.2015.12.021.
[78] Bernatsky S, Smargiassi A, Johnson M, Kaplan GG, Barnabe C, Svenson L, et al. Fine particulate air pollution, nitrogen dioxide, and systemic autoimmune rheumatic disease in Calgary, Alberta. Environ Res 2015;140:474–8. doi: 10.1016/j.envres.2015.05.007.
[79] Zhao N, Smargiassi A, Chen H, Widdifield J, Bernatsky S. Systemic autoimmune rheumatic diseases and multiple industrial air pollutant emissions: a large general population Canadian cohort analysis. Environ Int 2023;174:107920. doi: 10.1016/j.envint.2023.107920.
[80] Zhao N, Smargiassi A, Jean S, Gamache P, Laouan-Sidi EA, Chen H, et al. Long-term exposure to fine particulate matter and ozone and the onset of systemic autoimmune rheumatic diseases: an open cohort study in Quebec, Canada. Arthritis Res Ther 2022;24(1):151. doi: 10.1186/s13075-022-02843-5.
[81] Adami G, Fassio A, Pontalti M, Benini C, Gatti D, Rossini M. Association between long-term exposure to air pollution and immune-mediated diseases: a population-based cohort study. Bone Rep 2022;16:101440. doi: 10.1016/j.bonr.2022.101440.

[82] Park JS, Choi S, Kim K, Chang J, Kim SM, Kim SR, et al. Association of particulate matter with autoimmune rheumatic diseases among adults in South Korea. Rheumatology (Bulgaria) 2021;60(11):5117–26. doi: 10.1093/rheumatology/keab127.
[83] Faustini A, Renzi M, Kirchmayer U, Balducci M, Davoli M, Forastiere F. Short-term exposure to air pollution might exacerbate autoimmune diseases. Environ Epidemiol 2018;2(3). doi: 10.1097/EE9.0000000000000025.
[84] Chau TT, Wang KY. An association between air pollution and daily most frequently visits of eighteen outpatient diseases in an industrial city. Sci Rep 2020;10(1):2321. doi: 10.1038/s41598-020-58721-0.
[85] Adami G, Rossini M, Viapiana O, Orsolini G, Bertoldo E, Pontalti M, et al. Environmental air pollution is a predictor of poor response to biological drugs in chronic inflammatory arthritides. ACR Open Rheumatol 2021;3(7):451–6. doi: 10.1002/acr2.11270.
[86] Ziadé N, Bouzamel M, Mrad-Nakhlé M, Abi Karam B, Hmamouchi I, Abouqal R, et al. Prospective correlational time-series analysis of the influence of weather and air pollution on joint pain in chronic rheumatic diseases. Clin Rheumatol 2021;40(10):3929–40. doi: 10.1007/s10067-021-05735-2.
[87] Santacroce L, Dellaripa P, Costenbader K, Collins J, Feldman C. Association of area-level heat and social vulnerability with recurrent hospitalizations among individuals with rheumatic conditions. Arthritis Care Res (Hoboken) 2023;75(1):22–33. doi: 10.1002/acr.25015.
[88] Zhao D, Cheng J, Bao P, Zhang Y, Liang F, Wang H, et al. Effect of ambient temperature on outpatient admission for osteoarthritis and rheumatoid arthritis in a subtropical Chinese city. BMC Public Health 2022;22(1):172. doi: 10.1186/s12889-021-11994-0.
[89] Olsen MN, Tangvik RJ, Halse AK. Evaluation of Nutritional Status and Methods to Identify Nutritional Risk in Rheumatoid Arthritis and Spondyloarthritis. Nutrients 2020;12(11). doi: 10.3390/nu12113571.
[90] Chen HH, Lin CH, Hsieh TY, Chen DY, Ying JC, Chao WC. Factors associated with incident severe pulmonary arterial hypertension in systemic autoimmune rheumatic diseases: a nationwide study. Rheumatology (Oxford) 2021;60(11):5351–61. doi: 10.1093/rheumatology/keab118.
[91] Tsai CY, Su CL, Wang YH, Wu SM, Liu WT, Hsu WH, et al. Impact of lifetime air pollution exposure patterns on the risk of chronic disease. Environ Res 2023;229:115957. doi: 10.1016/j.envres.2023.115957.
[92] Jung CR, Chen WT, Lin YT, Hwang BF. Ambient air pollutant exposures and hospitalization for kawasaki disease in taiwan: a case-crossover study (2000-2010). Environ Health Perspect 2017;125(4):670–6. doi: 10.1289/EHP137.
[93] Yorifuji T, Tsukahara H, Kashima S, Doi H. Intrauterine and early postnatal exposure to particulate air pollution and kawasaki disease: a nationwide longitudinal survey in Japan. J Pediatr 2018;193:147–54 e2. doi: 10.1016/j.jpeds.2017.10.012.
[94] Buteau S, Belkaibech S, Bilodeau-Bertrand M, Hatzopoulou M, Smargiassi A, Auger N. Association between kawasaki disease and prenatal exposure to ambient and industrial air pollution: a population-based cohort study. Environ Health Perspec 2020;128(10):107006. doi: 10.1289/EHP6920.
[95] Kuo NC, Lin CH, Lin MC. Prenatal and early life exposure to air pollution and the incidence of Kawasaki disease. Sci Rep 2022;12(1):3415. doi: 10.1038/s41598-022-07081-y.
[96] Kwon D, Choe YJ, Kim SY, Chun BC, Choe SA. Ambient air pollution and kawasaki disease in korean children: a study of the national health insurance claim data. J Am Heart Assoc 2022;11(9):e024092. doi: 10.1161/JAHA.121.024092.
[97] Zeft AS, Burns JC, Yeung RS, McCrindle BW, Newburger JW, Dominguez SR, et al. Kawasaki disease and exposure to fine particulate air pollution. J Pediatr 2016;177:179–83 e1. doi: 10.1016/j.jpeds.2016.06.061.
[98] Fujii F, Egami N, Inoue M, Koga H. Weather condition, air pollutants, and epidemics as factors that potentially influence the development of Kawasaki disease. Sci Total Environ 2020;741:140469. doi: 10.1016/j.scitotenv.2020.140469.
[99] Ballester J, Burns JC, Cayan D, Nakamura Y, Uehara R, Rodó X. Kawasaki disease and ENSO-driven wind circulation. Geophys Res Lett 2013;40(10):2284–9. doi: 10.1002/grl.50388.
[100] Rodó X, Ballester J, Cayan D, Melish ME, Nakamura Y, Uehara R, et al. Association of Kawasaki disease with tropospheric wind patterns. Sci Rep 2011;1(1):152. doi: 10.1038/srep00152.
[101] Burns JC, Herzog L, Fabri O, Tremoulet AH, Rodo X, Uehara R, et al. Seasonality of kawasaki disease: a global perspective. PLoS ONE 2013;8(9):e74529. doi: 10.1371/journal.pone.0074529.
[102] Corinaldesi E, Pavan V, Andreozzi L, Fabi M, Selvini A, Frabboni I, et al. Environmental factors and Kawasaki disease onset in emilia-romagna, Italy. Int J Environ Res Public Health 2020;17(5). doi: 10.3390/ijerph17051529.
[103] Oh J, Lee JH, Kim E, Kim S, Kim HS, Ha E. Is short-term exposure to pm 2.5 relevant to childhood Kawasaki disease? Int J Environ Res Public Health 2021;18(3). doi: 10.3390/ijerph18030924.
[104] Foocharoen C, Peansukwech U, Pongkulkiat P, Mahakkanukrauh A, Suwannaroj S. Aerosol components associated with hospital mortality in systemic sclerosis: an analysis from a nationwide Thailand healthcare database. Sci Rep 2021;11(1):7983. doi: 10.1038/s41598-021-87114-0.
[105] Cereda E, Codullo V, Klersy C, Breda S, Cripa A, Rava ML, et al. Disease-related nutritional risk and mortality in systemic sclerosis. Clin Nutr 2014;33(3):558–61. doi: 10.1016/j.clnu.2013.08.010.
[106] Cruz-Domínguez MP, García-Collinot G, Saavedra MA, Montes-Cortes DH, Morales-Aguilar R, Carranza-Muleiro RA, et al. Malnutrition is an independent risk factor for mortality in Mexican patients with systemic sclerosis: a cohort study. Rheumatol Int 2017;37(7):1101–9. doi: 10.1007/s00296-017-3753-y.
[107] Rosato E, Gigante A, Pellicano C, Colalillo A, Alunni-Fegatelli D, Muscaritoli M. Phase angle, nutritional status, and mortality in systemic sclerosis: an exploratory pilot study. Nutrition 2023;107:111946. doi: 10.1016/j.nut.2022.111946.
[108] Paolino S, Pacini G, Schenone C, Patane M, Sulli A, Sukkar SG, et al. Nutritional status and bone microarchitecture in a cohort of systemic sclerosis patients. Nutrient 2020;12(6). doi: 10.3390/nu12061632.
[109] Läubli J, Dobrota R, Maurer B, Jordan S, Misselwitz B, Fox M, Distler O. Impaired micronutrients and prealbumin in patients with established and very early systemic sclerosis. Clin Exp Rheumatol 2020;38(3):120–6 Suppl 125Epub 2020 Jul 29. PMID: 32828144.
[110] Caimmi C, Caramaschi P, Venturini A, Bertoldo E, Vantaggiato E, Viapiana O, et al. Malnutrition and sarcopenia in a large cohort of patients with systemic sclerosis. Clin Rheumatol 2018;37(4):987–97. doi: 10.1007/s10067-017-3932-y.
[111] Dupont R, Longué M, Galinier A, frais CC, Ingueneau C, Astudillo L, et al. Impact of micronutrient deficiency & malnutrition in systemic sclerosis: cohort study and literature review. Autoimmun Rev 2018;17(11):1081–9. doi: 10.1016/j.autrev.2018.05.010.
[112] Rosato E, Gigante A, Gasperini ML, Proietti L, Muscaritoli M. Assessing malnutrition in systemic sclerosis with global leadership initiative on malnutrition and european society of clinical nutrition and metabolism criteria. JPEN J Parenter Enteral Nutr 2021;45(3):618–24. doi: 10.1002/jpen.1872.
[113] Türk İ, Cüzdan N, Çiftçi V, Arslan D, Doğan MC. Unal İ. Malnutrition, associated clinical factors, and depression in systemic sclerosis: a cross-sectional study. Clin Rheumatol 2020;39(1):57–67. doi: 10.1007/s10067-019-04598-y.
[114] Rosato E, Gigante A, Gasperini ML, Molinaro I, Di Lazzaro Giraldi G, Afeltra A, et al. Nutritional status measured by BMI is impaired and correlates with left ventricular mass in patients with systemic sclerosis. Nutrition 2014;30(2):204–9. doi: 10.1016/j.nut.2013.07.025.
[115] Borghini A, Poscia A, Bosello S, Teleman AA, Bocci M, Iodice L, et al. Environmental Pollution by Benzene and PM(10) and Clinical Manifestations of Systemic Sclerosis: a Correlation Study. Int J Environ Res Public Health 2017;14(11). doi: 10.3390/ijerph14111297.
[116] Galperín G, Berra M, Marquez MI, Mandaradoni M, Tau J, Berra A. Impact of environmental pollution on the ocular surface of Sjögren's syndrome patients. Arq Bras Oftalmol 2018;81(6):481–9. doi: 10.5935/0004-2749.20180091.
[117] Zhang TP, Wang LJ, Wang S, Wang P, Zhou XH, Wang L, et al. Exposure to ambient gaseous pollutant and daily hospitalizations for Sjögren's syndrome in Hefei: a time-series study. Front Immunol 2022;13:1028893. doi: 10.3389/fimmu.2022.1028893.
[118] Zhang TP, Dou J, Wang L, Wang S, Wang P, Zhou XH, et al. Exposure to particulate pollutant increases the risk of hospitalizations for Sjögren's syndrome. Front Immunol 2022;13:1059981. doi: 10.3389/fimmu.2022.1059981.
[119] Chen Y, He YS, Feng YT, Wu ZK, Wang J, Yin KJ, et al. The effect of air pollution exposure on risk of outpatient visits for Sjogren's syndrome: a time-series study. Environ Res 2022;214(Pt 3):114017. doi: 10.1016/j.envres.2022.114017.
[120] Wang H, Jia H, Han J, Zhang Z, Yin X, Mu N, et al. Correlation between air quality index and tear film lipid layer thickness: comparison between patients with Sjogren's syndrome and with meibomian gland dysfunction. Curr Eye Res 2023;48(5):447–55. doi: 10.1080/02713683.2023.2167213.
[121] Ma KSK, Wang LT, Chong W, Lin CL, Li H, Chen A, et al. Exposure to environmental air pollutants as a risk factor for primary Sjögren's syndrome. Front Immunol 2023;13:1044462. doi: 10.3389/fimmu.2022.1044462.
[122] Xin L, Zhu Y, Liu J, Fang Y, Xie J. Exposure-lag-response associations between extreme environmental conditions and primary Sjögren's syndrome. Clin Rheumatol 2022;41(2):523–32. doi: 10.1007/s10067-021-05910-5.
[123] Pearson DR, Werth VP. Geospatial correlation of amyopathic dermatomyositis with fixed sources of airborne pollution: a retrospective cohort study. Front Med (Lausanne) 2019;6(APR). doi: 10.3389/fmed.2019.00085.
[124] Orione MA, Silva CA, Sallum AM, Campos LMA, Omori CH, Braga ALF, et al. Risk factors for juvenile dermatomyositis: exposure to tobacco and air pollutants during pregnancy. Arthritis Care Res (Hoboken) 2014;66(10):1571–5. doi: 10.1002/acr.22358.
[125] Wu ZD, Chen C, He YS, Chen Y, Feng YT, Huang JX, et al. Association between air pollution exposure and outpatient visits for dermatomyositis in a humid subtropical region of China: a time-series study. Environ Geochem Health 2023;45(8):6095–107. doi: 10.1007/s10653-023-01616-6.
[126] Parks CG, Wilkerson J, Rose KM, Faiq A, Farhadi PN, Long CS, et al. Association of ultraviolet radiation exposure with dermatomyositis in a national myositis patient registry. Arthritis Care Res (Hoboken) 2020;72(11):1636–44. doi: 10.1002/acr.24059.
[127] Neely J, Long CS, Sturrock H, Kim S. Association of short-term ultraviolet radiation exposure and disease severity in juvenile dermatomyositis: results from the childhood arthritis and rheumatology research alliance legacy registry. Arthritis Care Res (Hoboken) 2019;71(12):1600–5. doi: 10.1002/acr.23840.
[128] Shah M, Targoff IN, Rice MM, Miller FW, Rider LG. Ultraviolet radiation exposure is associated with clinical and autoantibody phenotypes in Juvenile myositis. Arthritis Rheum. 2013;65(7):1934–41. doi: 10.1002/art.37985.
[129] Bellinato F, Adami G, Vaienti S, Benini C, Gatti D, Idolazzi L, et al. Association between short-term exposure to environmental air pollution and psoriasis flare. JAMA Dermatol 2022;158(4):375–81 1. doi: 10.1001/jamadermatol.2021.6019.
[130] Kao CM, Chen YM, Huang WN, Chen YH, Chen HH. Association between air pollutants and initiation of biological therapy in patients with ankylosing spondylitis: a nationwide, population-based, nested case-control study. Arthritis Res Ther 2023;25(1):75. doi: 10.1186/s13075-023-03060-4.
[131] Soleimanifar N, Nicknam MH, Bidad K, Jamshidi AR, Mahmoudi M, Mostafaei S, et al. Effect of food intake and ambient air pollution exposure on ankylosing

spondylitis disease activity. Adv Rheumatol 2019;59(1):9. doi: 10.1186/s42358-019-0051-2.
[132] Xin L, Liu J, Zhu Y, Fang Y. Exposure-lag-response associations between weather conditions and ankylosing spondylitis: a time series study. BMC Musculoskelet Disord 2021;22(1):641. doi: 10.1186/s12891-021-04523-y.
[133] Triggianese P, Caso F, Della Morte D, D Antonio A, Ferrigno S, Fatica M, et al. Micronutrients deficiencies in patients with spondylarthritis: the potential immunometabolic crosstalk in disease phenotype. Eur Rev Med Pharmacol Sci 2022;26(6):2025–35. doi: 10.26355/eurrev_202203_28351.
[134] Ryu HJ, Seo MR, Choi HJ, Cho J, Baek HJ. Particulate matter (PM10)) as a newly identified environmental risk factor for acute gout flares: a time-series study. Joint Bone Spine 2021;88(2):105108. doi: 10.1016/j.jbspin.2020.105108.
[135] Hu WS, Lin CL. Effect of air pollution on gout development: a nationwide population-based observational study. QJM 2021;114(7):471–5. doi: 10.1093/qjmed/hcaa286.
[136] He YS, Wang GH, Wu Q, Wu ZD, Chen Y, Tao JH, et al. The relationship between ambient air pollution and hospitalizations for gout in a humid subtropical region of China. J Inflamm Res 2021;14:5827–35.
[137] He YS, Wang GH, Wu ZD, Sam NB, Chen Y, Tao JH, et al. Association between non-optimal temperature and hospitalizations for gout in Anqing, China: a time-series analysis. Environ Sci Pollut Res Int 2022;29(10):13797–804. doi: 10.1007/s11356-021-16580-w.
[138] Neogi T, Chen C, Niu J, Chaisson C, Hunter DJ, Choi H, et al. Relation of temperature and humidity to the risk of recurrent gout attacks. Am J Epidemiol 2014;180(4):372–7. doi: 10.1093/aje/kwu147.
[139] Chen H, Wu J, Wang M, Wang S, Wang J, Yu H, et al. Impact of exposure to ambient fine particulate matter pollution on adults with knee osteoarthritis. Int J Environ Res Public Health 2021;18(18). doi: 10.3390/ijerph18189644.
[140] Liu JF, Chi MC, Lin CY, Lee CW, Chang TM, Han CK, et al. PM2.5 facilitates IL-6 production in human osteoarthritis synovial fibroblasts via ASK1 activation. J Cell Physiol 2021;236(3):2205–13. doi: 10.1002/jcp.30009.
[141] Ferreira ML, Zhang Y, Metcalf B, Makovey J, Bennell KL, March L, et al. The influence of weather on the risk of pain exacerbation in patients with knee osteoarthritis - a case-crossover study. Osteoarthritis Cartilage 2016;24(12):2042–7. doi: 10.1016/j.joca.2016.07.016.
[142] Brennan SA, Harney T, Queally JM, O'Connor McGoona J, Gormley IC, Shannon FJ. Influence of weather variables on pain severity in end-stage osteoarthritis. Int Orthop 2012;36(3):643–6. doi: 10.1007/s00264-011-1304-9.
[143] Fernandes EC, Silva CA, Braga AL, Sallum AM, Campos LM, Farhat SC. Exposure to air pollutants and disease activity in juvenile-onset systemic lupus erythematosus patients. Arthritis Care Res (Hoboken) 2015;67(11):1609–14. doi: 10.1002/acr.22603.
[144] Goulart MFG, Alves AGF, Farhat J, Braga SLF, Pereira LAA, de Faria Coimbra Lichtenfeis AJ, et al. Influence of air pollution on renal activity in patients with childhood-onset systemic lupus erythematosus. Pediatr Nephrol 2020;35(7):1247–55. doi: 10.1007/s00467-020-04517-3.
[145] Farhat SCL, Ejnisman C, Alves AGF, Goulart MFG, Lichtenfeis AJFC, Braga ALF, et al. Air pollution influence on serum inflammatory interleukins: a prospective study in childhood-onset systemic lupus erythematosus patients. Lupus 2021;30 (14):2268–75. doi: 10.1177/09612033211061479.
[146] Alves AGF, de Azevedo Giacomin MF, Braga ALF, Sallum AME, Pereira LAA, Farhat LC, et al. Influence of air pollution on airway inflammation and disease activity in childhood-systemic lupus erythematosus. Clin Rheumatol 2018;37(3):683–90. doi: 10.1007/s10067-017-3893-1.
[147] Zhao N, Al-Aly Z, Zheng B, van Donkelaar A, Martin RV, Pineau CA, et al. Fine particulate matter components and interstitial lung disease in rheumatoid arthritis. Eur Respir J 2022;60(1). doi: 10.1183/13993003.02149-2021.
[148] Roeser A, Sese L, Chassagnon G, Chaigne B, Dunogue B, Tran Ba S, et al. The association between air pollution and the severity at diagnosis and progression of systemic sclerosis-associated interstitial lung disease: results from the retrospective ScleroPol study. Respir Res 2023;24(1):151. doi: 10.1186/s12931-023-02463-w.
[149] Liu B, Sun G, Liu Y, Hou Y. Observational studies: ambient air pollution and hospitalization for RA-ILD in a heavily polluted city in China. Medicine (Baltimore) 2022;101(19):e29309. doi: 10.1097/MD.0000000000029309.
[150] Chen HH, Yong YM, Lin CH, Chen YH, Chen DY, Ying JC, et al. Air pollutants and development of interstitial lung disease in patients with connective tissue disease: a population-based case-control study in Taiwan. BMJ Open 2020;10(12): e041405. doi: 10.1136/bmjopen-2020-041405.
[151] França CMP, Sallum AME, Braga ALF, Strufaldi FL, Silva CAA, Farhat SCL. Risk factors associated with juvenile idiopathic arthritis: exposure to cigarette smoke and air pollution from pregnancy to disease diagnosis. J Rheumatol 2018;45 (2):248–56. doi: 10.3899/jrheum.161500.
[152] Zeft AS, Prahalad S, Lefevre S, Clifford B, McNally B, Bohnsack JF, et al. Juvenile idiopathic arthritis and exposure to fine particulate air pollution. Clin Exp Rheumatol 2009;27(5):877–84 PMID: 19917177.
[153] Zeft AS, Prahalad S, Schneider R, Dedeoglu F, Weiss PF, Grom AA, et al. Systemic onset juvenile idiopathic arthritis and exposure to fine particulate air pollution. Clin Exp Rheumatol 2016;34(5):946–52 Epub 2016 Sep 1. PMID: 27607024.
[154] Wu YH, Yu-Fong Chang J, Wang YP, Wu YC, Chen HM, Sun A. Hemoglobin, iron, vitamin B12, and folic acid deficiencies and hyperhomocysteinemia in Behcet's disease patients with atrophic glossitis. J Formos Med Assoc 2018;117(7):559–65. doi: 10.1016/j.jfma.2018.03.005.
[155] Erdoğan S, Sorgun MH, Kuzu Mumcu M, Kural MA, Rzayev S, Yücesan C. Nutritional Status in patients with Neuro-Behçet's disease. Turk J Med Sci 2021;51 (4):1682–8. doi: 10.3906/sag-2009-235.
[156] Kuo YS, Chang JY, Wang YP, Wu YC, Wu YH, Sun A. Significantly higher frequencies of hemoglobin, iron, vitamin B12, and folic acid deficiencies and of hyperhomocysteinemia in patients with Behcet's disease. J Formos Med Assoc 2018;117 (10):932–8. doi: 10.1016/j.jfma.2018.04.007.
[157] Yamamoto SS, Yacyshyn E, Jhangri GS, Chopra A, Parmar D, Jones CA. Household air pollution and arthritis in low-and middle-income countries: cross-sectional evidence from the World Health Organization's study on Global Ageing and Adult Health. PLoS ONE 2019;14(12):e0226738. doi: 10.1371/journal.pone.0226738.
[158] Rustler P, Schindler D, Guler SA, Müller-Quernheim J, Voll R, Kollert F. Acute sarcoidosis clusters in cold season and is associated with ambient air pollution: a retrospective clinical−meteorological study. Annals ATS 2021;18(8):1415–7. doi: 10.1513/AnnalsATS.202008-1083RL.
[159] Vidotto JP, Pereira LA, Braga AL, Silva CA, Sallum AM, Campos LM, et al. Atmospheric pollution: influence on hospital admissions in paediatric rheumatic diseases. Lupus 2012;21(5):526–33. doi: 10.1177/0961203312437806.
[160] Wang CM, Jung CR, Chen WT, Hwang BF. Exposure to fine particulate matter (PM 2.5) and pediatric rheumatic diseases. Environ Int 2020;138:105602. doi: 10.1016/j.envint.2020.105602.
[161] Wang Z, Zou Z, Dong B, Ma J, Arnold L. Association between the Great China Famine exposure in early life and risk of arthritis in adulthood. J Epidemiol Community Health 2018;72(9):790–5. doi: 10.1136/jech-2017-210334.
[162] Sendur OF, Tastaban E, Turan Y, Ulman C. The relationship between serum trace element levels and clinical parameters in patients with fibromyalgia. Rheumatol Int 2008;28(11):1117–21. doi: 10.1007/s00296-008-0593-9.
[163] Fagerlund AJ, Iversen M, Ekeland A, Moen CM, Aslaksen PM. Blame it on the weather? The association between pain in fibromyalgia, relative humidity, temperature and barometric pressure. PLoS ONE 2019;14(5):e0216902. doi: 10.1371/journal.pone.0216902.
[164] Weiner M, Bjørneklett R, Hrušková Z, Mackinnon B, Poulton CJ, Sindelar L, et al. Proteinase-3 and myeloperoxidase serotype in relation to demographic factors and geographic distribution in anti-neutrophil cytoplasmic antibody-associated glomerulonephritis. Nephrol Dial Transplant 2019;34(2):301–8. doi: 10.1093/ndt/gfy106.
[165] Ulysse SN, Chandler MT, Santacroce L, Cai T, Liao KP, Feldman CH. Social determinants of health documentation among individuals with rheumatic and musculoskeletal conditions in an integrated care management program. Arthritis Care Res (Hoboken) 2023;75(12):2529–36. doi: 10.1002/acr.25174.
[166] Smedslund G, Eide H, Kristjansdottir ÓB, Nes AAG, Sexton H, Fors EA. Do weather changes influence pain levels in women with fibromyalgia, and can psychosocial variables moderate these influences? Int J Biometeorol 2014;58 (7):1451–7. doi: 10.1007/s00484-013-0747-7.
[167] Scott J, Havyarimana E, Navarro-Gallinad A, White A, Wyse J, van Geffn J, et al. The association between ambient UVB dose and ANCA-associated vasculitis relapse and onset. Arthritis Res Ther 2022;24(1):147. doi: 10.1186/s13075-022-02834-6.
[168] IQAir. World's most polluted countries & regions. https://www.iqair.com/us/world-most-polluted-countries (accessed 15 December 2023).
[169] Ehsan ER, Webber H, Asseng S, Boote K, Durand JL, Ewert F, Martyr P, MacCarthy DS. Climate change impacts on crop yields. Nature Reviews Earth and Environment 2023;4:831–46. doi: 10.1038/s43017-023-00491-0.
[170] Zhu P, Burney J, Chang J, Jing Z, Mueller ND, Xin Q, Xu J, Yu L, Makowski D, Ciais P. Warming reduces global agricultural production by decreasing cropping frequency and yields. Nat Clim Chang 2022;12(11):1016–23. doi: 10.1038/s41558-022-01492.
[171] Zamansky GB. Sunlight-induced pathogenesis in systemic lupus erythematosus. J Invest Dermatol 1985;85(3):179–80. doi: 10.1111/1523-1747.ep12276644.
[172] Foering K, Chang AY, Piette EW, Cucchiara A, Okawa J, Werth VP. Characterization of clinical photosensitivity in cutaneous lupus erythematosus. J Am Acad Dermatol 2013;69(2):205–13. doi: 10.1016/j.jaad.2013.03.015.
[173] Sintayehu DW, Tassie N, De Boer WF. Present and future climatic suitability for dengue fever in Africa. Infect Ecol Epidemiol 2020;10(1):1782042. doi: 10.1080/20008686.2020.1782042.
[174] Mweya CN, Kimera SI, Stanley G, Misinzo G, Mboera LE. Climate change influences potential distribution of infected aedes aegypti Co-occurrence with dengue epidemics risk areas in Tanzania. PLoS ONE 2016;11(9):e0162649. doi: 10.1371/journal.pone.0162649.
[175] Cheng J, Bambrick H, Yakob L, Devine G, Frentiu FD, Williams G, et al. Extreme weather conditions and dengue outbreak in Guangdong, China: spatial heterogeneity based on climate variability. Environ Res 2021;196:110900. doi: 10.1016/j.envres.2021.110900.
[176] Liu H, Huang X, Guo X, Cheng P, Wang H, Liu L, et al. Climate change and Aedes albopictus risks in China: current impact and future projection. Infect Dis Poverty 2023;12(1):26. doi: 10.1186/s40249-023-01083-2.
[177] Wu W, Ren H, Lu L. Increasingly expanded future risk of dengue fever in the Pearl River Delta, China. PLoS Negl Trop Dis 2021;15(9):e0009745. doi: 10.1371/journal.pntd.0009745.
[178] Li C, Liu Z, Li W, et al. Projecting future risk of dengue related to hydrometeorological conditions in mainland China under climate change scenarios: a modelling study. Lancet Planet Health 2023;7(5):e397–406. doi: 10.1016/S2542-5196(23)00051-7.
[179] Lee JS, SY Chung. The threat of climate change on tick-borne infections: rising trend of infections and geographic distribution of climate risk factors associated with ticks. J Infect Dis 2023;227(2):295–303. doi: 10.1093/infdis/jiac300.
[180] Bonnin L, Tran A, Herbreteau V, Marcombe S, Boyer S, Mangeas M, et al. Predicting the effects of climate change on dengue vector densities in southeast Asia

through process-based modeling. Environ Health Perspect 2022;130 (12):127002. doi: 10.1289/EHP11068.
[181] Bett B, Grace D, Lee HS, Lindahl J, Nguyen-Viet H, Phuc PD, et al. Spatiotemporal analysis of historical records (2001-2012) on dengue fever in Vietnam and development of a statistical model for forecasting risk. PLoS ONE 2019;14(11): e0224353. doi: 10.1371/journal.pone.0224353.
[182] Huang X, Yakob L, Devine G, Frentiu FD, Fu SY, Hu W. Dynamic spatiotemporal trends of imported dengue fever in Australia. Sci Rep 2016;6:30360. doi: 10.1038/srep30360.
[183] Beebe NW, Cooper RD, Mottram P, Sweeney AW. Australia's dengue risk driven by human adaptation to climate change. PLoS Negl Trop Dis 2009;3(5):e429. doi: 10.1371/journal.pntd.0000429.
[184] Henry S, Mendonça AFA. Past, present, and future vulnerability to dengue in jamaica: a spatial analysis of monthly variations. Int J Environ Res Public Health 2020;17(9). doi: 10.3390/ijerph17093156.
[185] Bouzid M, Colón-González FJ, Lung T, Lake IR, Hunter PR. Climate change and the emergence of vector-borne diseases in Europe: case study of dengue fever. BMC Public Health 2014;14:781. doi: 10.1186/1471-2458-14-781.
[186] Liu-Helmersson J, Quam M, Wilder-Smith A, Stenlund H, Ebi K, Massad E, et al. Climate change and aedes vectors: 21st century projections for dengue transmission in Europe. EBioMedicine 2016;7:267–77. doi: 10.1016/j.ebiom.2016.03.046.
[187] Ivanescu LM, Bodale I, Grigore-Hristodorescu S, Martinescu G, Andronic B, Matiut S, et al. The risk of emerging of dengue fever in romania, in the context of global warming. Trop Med Infect Dis 2023;8(1). doi: 10.3390/tropicalmed8010065.
[188] Aström C, Rocklöv J, Hales S, Béguin A, Louis V, Sauerborn R. Potential distribution of dengue fever under scenarios of climate change and economic development. Ecohealth 2012;9(4):448–54. doi: 10.1007/s10393-012-0808-0.
[189] Colón-González FJ, Sewe MO, Tompkins AM, Sjodin H, Casallas A, Rocklov J, et al. Projecting the risk of mosquito-borne diseases in a warmer and more populated world: a multi-model, multi-scenario intercomparison modelling study. Lancet Planet Health 2021;5(7):e404–14. doi: 10.1016/S2542-5196(21)00132-7.
[190] Liu-Helmersson J, Stenlund H, Wilder-Smith A, Rocklöv J. Vectorial capacity of Aedes aegypti: effects of temperature and implications for global dengue epidemic potential. PLoS ONE 2014;9(3):e89783. doi: 10.1371/journal.pone.0089783.
[191] Messina JP, Brady OJ, Golding N, Kraemer MUG, Wint GRW, Ray SE, et al. The current and future global distribution and population at risk of dengue. Nat Microbiol 2019;4(9):1508–15. doi: 10.1038/s41564-019-0476-8.
[192] Barcellos C, Lowe R. Expansion of the dengue transmission area in Brazil: the role of climate and cities. Trop Med Int Health 2014;19(2):159–68. doi: 10.1111/tmi.12227.
[193] Rodrigues NCP, Lino VTS, Daumas RP, et al. Temporal and spatial evolution of dengue incidence in Brazil, 2001-2012. PLoS ONE 2016;11(11). doi: 10.1371/journal.pone.0165945.
[194] Lee SA, Economou T, de Castro Catão R, Barcellos C, Lowe R. The impact of climate suitability, urbanisation, and connectivity on the expansion of dengue in 21st century Brazil. PLoS Negl Trop Dis 2021;15(12):e0009773. doi: 10.1371/journal.pntd.0009773.
[195] Colón-González FJ, Harris I, Osborn TJ, Lake IR. Limiting global-mean temperature increase to 1.5-2°C could reduce the incidence and spatial spread of dengue fever in Latin America. Proc Natl Acad Sci U S A 2018;115(24):6243–8. doi: 10.1073/pnas.1718945115.
[196] Ferreira MC. Geographical distribution of the association between El Niño South Oscillation and dengue fever in the Americas: a continental analysis using geographical information system-based techniques. Geospat Health 2014;9 (1):141–51. doi: 10.4081/gh.2014.12.
[197] Lozano-Fuentes S, Hayden MH, Welsh-Rodriguez C, Ochoa-Martinez C, Tapia-Santos B, Kobylinski KC, et al. The dengue virus mosquito vector Aedes aegypti at high elevation in México. Am J Tropic Med Hyg 2012;87(5):902–9. doi: 10.4269/ajtmh.2012.12-0244.
[198] Nelson S, Jenkins A, Jupiter SD, Horowitz P, Mangubhai S, Abimbola S, et al. Predicting climate-sensitive water-related disease trends based on health, seasonality and weather data in Fiji. J Clim Cha Health 2022;6. doi: 10.1016/j.joclim.2022.100112.
[199] Butterworth MK, Morin CW, Comrie AC. An Analysis of the Potential Impact of Climate Change on Dengue Transmission in the Southeastern United States. Environ Health Perspect 2017;125(4):579–85. doi: 10.1289/EHP218.
[200] Hussain SSA, Dhiman RC. Distribution Expansion of Dengue Vectors and Climate Change in India. Geohealth 2022;6(6):e2021GH000477. doi: 10.1029/2021GH000477.
[201] Kakarla SG, Bhimala KR, Kadiri MR, Kumaraswamy S, Mutheneni SR. Dengue situation in India: suitability and transmission potential model for present and projected climate change scenarios. Sci Total Environ 2020;739:140336. doi: 10.1016/j.scitotenv.2020.140336.
[202] Karuppusamy B, Sarma DK, Lalmalsawma P, Pautu L, Karmodiya K, Balabaskaran Nina P. Effect of climate change and deforestation on vector borne diseases in the North-Eastern Indian State of Mizoram bordering Myanmar. J Clim Cha Health 2021;2. doi: 10.1016/j.joclim.2021.100015.
[203] Acharya BK, Cao C, Xu M, Khanal L, Naeem S, Pandit S. Present and future of dengue fever in Nepal: mapping climatic suitability by ecological niche model. Int J Environ Res Public Health 2018;15(2). doi: 10.3390/ijerph15020187.
[204] Davis C, Murphy AK, Bambrick H, Devine GJ, Frentiu FD, Yakob L, et al. A regional suitable conditions index to forecast the impact of climate change on dengue vectorial capacity. Environ Res 2021;195:110849. doi: 10.1016/j.envres.2021.110849.
[205] Cardoso-Leite R, Vilarinho AC, Novaes MC, Tonetto AF, Vilardi GC, Guillermo-Ferreira R. Recent and future environmental suitability to dengue fever in Brazil using species distribution model. Trans. R. Soc. Trop. Med. Hyg. 2014;108(2):99–104. doi: 10.1093/trstmh/trt115.
[206] Trejo I, Barnard M, Spencer JA, Keithley J, Martinez KM, Crooker I, et al. Changing temperature profiles and the risk of dengue outbreaks. PLOS Clim 2023;2(2): e0000115. doi: 10.1371/journal.pclm.0000115.
[207] Lee JS, Farlow A. The threat of climate change to non-dengue-endemic countries: increasing risk of dengue transmission potential using climate and non-climate datasets. BMC Public Health 2019;19(1):934. doi: 10.1186/s12889-019-7282-3.
[208] Cunze S, Glock G, Klimpel S. Spatial and temporal distribution patterns of tick-borne diseases (Tick-borne Encephalitis and Lyme Borreliosis) in Germany. PeerJ 2021;9:e12422. doi: 10.7717/peerj.12422.
[209] Nolzen H, Brugger K, Reichold A, Brock J, Lange M, Thulke HH. Model-based extrapolation of ecological systems under future climate scenarios: the example of Ixodes ricinus ticks. PLoS ONE 2022;17(4):e0267196. doi: 10.1371/journal.pone.0267196.
[210] Kjær LJ, Soleng A, Edgar KS, Lindstedt HEH, Paulsen KM, Andreassen AK, et al. Predicting and mapping human risk of exposure to ixodes ricinus nymphs using climatic and environmental data, Denmark, Norway and Sweden, 2016. Eurosurveillance 2019;24(9). doi: 10.2807/1560-7917.ES.2019.24.9.1800101.
[211] Li S, Gilbert L, Harrison PA, Rounsevell MD. Modelling the seasonality of Lyme disease risk and the potential impacts of a warming climate within the heterogeneous landscapes of Scotland. J R Soc Interface 2016;13(116). doi: 10.1098/rsif.2016.0140.
[212] Leibovici DG, Bylund H, Björkman C, Tokarevich N, Thierfelder T, Evengard B, et al. Associating Land cover changes with patterns of incidences of climate-sensitive infections: an example on tick-borne diseases in the nordic Area. Int J Environ Res Public Health 2021;18(20). doi: 10.3390/ijerph182010963.
[213] Donša D, Grujić VJ, Pipenbaher N, Ivajnšič D. The lyme borreliosis spatial footprint in the 21st century: a key study of slovenia. Int J Environ Res Public Health 2021;18(22). doi: 10.3390/ijerph182212061.
[214] Jaenson TGT, Lindgren E. The range of Ixodes ricinus and the risk of contracting Lyme borreliosis will increase northwards when the vegetation period becomes longer. Ticks Tick-borne Dis 2011;2(1):44–9. doi: 10.1016/j.ttbdis.2010.10.006.
[215] Porretta D., Mastrantonio V., Amendolia S., Gaiarsa S., Epis S., Genchi C., et al. Effects of global changes on the climatic niche of the tick Ixodes ricinus inferred by species distribution modelling. Parasites Vect 201;6(1). https://doi.org/10.1186/1756-3305-6-271
[216] Alkishe AA, Peterson AT, Samy AM. Climate change influences on the potential geographic distribution of the disease vector tick Ixodes ricinus. PLoS ONE 2017;12(12):e0189092 5. doi: 10.1371/journal.pone.0189092.
[217] Simon JA, Marrotte RR, Desrosiers N, Fiset J, Gaitan J, Gonzalez A, et al. Climate change and habitat fragmentation drive the occurrence of Borrelia burgdorferi, the agent of Lyme disease, at the northeastern limit of its distribution. Evol Appl 2014;7(7):750–64. doi: 10.1111/eva.12165.
[218] Lieske DJ, Lloyd VK. Combining public participatory surveillance and occupancy modelling to predict the distributional response of Ixodes scapularis to climate change. Ticks Tick Borne Dis 2018;9(3):695–706. doi: 10.1016/j.ttbdis.2018.01.018.
[219] McPherson M, García-García A, Cuesta-Valero FJ, Beltrami H, Hansen-Ketchum P, MacDougall D, et al. Expansion of the lyme disease vector ixodes scapularis in canada inferred from CMIP5 climate projections. Environ Health Perspect 2017;125(5):057008. doi: 10.1289/EHP57.
[220] Ogden NH, St-Onge L, Barker IK, Brazeau S, Bigras-Poulin M, Charron DF, et al. Risk maps for range expansion of the Lyme disease vector, Ixodes scapularis, in Canada now and with climate change. Int J Health Geogr 2008;7:24. doi: 10.1186/1476-072X-7-24.
[221] Ogden NH, Radojevic M, Wu X, Duvvuri VR, Leighton PA, Wu J. Estimated effects of projected climate change on the basic reproductive number of the Lyme disease vector Ixodes scapularis. Environ Health Perspect 2014;122(6):631–8. doi: 10.1289/ehp.1307799.
[222] Monaghan AJ, Moore SM, Sampson KM, Beard CB, Eisen RJ. Climate change influences on the annual onset of Lyme disease in the United States. Ticks Tick Borne Dis 2015;6(5):615–22. doi: 10.1016/j.ttbdis.2015.05.005.
[223] Dumic I, Severnini E. Ticking Bomb": the impact of climate change on the incidence of lyme disease. Can J Infect Dis Med Microbiol 2018:5719081 2018. doi: 10.1155/2018/5719081.
[224] Hahn MB, Feirer S, Monaghan AJ, Lane RS, Eisen RJ, Padgett KA, et al. Modeling future climate suitability for the western blacklegged tick, Ixodes pacificus, in California with an emphasis on land access and ownership. Ticks Tick Borne Dis 2021;12(5). doi: 10.1016/j.ttbdis.2021.101789.
[225] Porter WT, Barrand ZA, Wachara J, DaVall K, Mihaljevic JR, Pearson T, et al. Predicting the current and future distribution of the western black-legged tick, Ixodes pacificus, across the Western US using citizen science collections. PLoS ONE 2021;16(1):e0244754. doi: 10.1371/journal.pone.0244754.
[226] Robinson SJ, Neitzel DF, Moen RA, Craft ME, Hamilton KE, Johnson LB, et al. Disease risk in a dynamic environment: the spread of tick-borne pathogens in Minnesota, USA. Ecohealth 2015;12(1):152–63. doi: 10.1007/s10393-014-0979-y.
[227] Yang X, Gao Z, Wang L, Xiao L, Dong N, Wu H, et al. Projecting the potential distribution of ticks in China under climate and land use change. Int J Parasitol 2021;51(9):749–59. doi: 10.1016/j.ijpara.2021.01.004.

[228] Li S, Gilbert L, Vanwambeke SO, Yu J, Purse BV, Harrison PA. Lyme disease risks in europe under multiple uncertain drivers of change. Environ Health Perspect 2019;127(6):67010. doi: 10.1289/EHP4615.
[229] Boeckmann M, Joyner TA. Old health risks in new places? An ecological niche model for I. ricinus tick distribution in Europe under a changing climate. Health Place 2014;30:70–7. doi: 10.1016/j.healthplace.2014.08.004.
[230] Fernández-Ruiz N, Estrada-Peña A. Could climate trends disrupt the contact rates between Ixodes ricinus (Acari, Ixodidae) and the reservoirs of Borrelia burgdorferi s.l.? PLoS ONE 2020;15(5):e0233771. doi: 10.1371/journal.pone.0233771.
[231] Zhang L, Ma D, Li C, Zhou R, Wang J, Liu Q. Projecting the potential distribution areas of Ixodes scapularis (Acari: ixodidae) driven by climate change. Biology (Basel) 2022;11(1). doi: 10.3390/biology11010107.
[232] Dong Y, Huang Z, Zhang Y, Wang YXG, La Y. Comparing the climatic and landscape risk factors for lyme disease cases in the upper midwest and Northeast United States. Int J Environ Res Public Health 2020;17(5). doi: 10.3390/ijerph17051548.
[233] Stevens LK, Kolivras KN, Hong Y, Thomas VA, Campbell JB, Prisley SP. Future Lyme disease risk in the south-eastern United States based on projected land cover. Geospat Health 2019;14(1). doi: 10.4081/gh.2019.751.
[234] Dhingra R, Jimenez V, Chang HH, Gambhir M, Fu JS, Liu Y. Spatially-explicit simulation modeling of ecological response to climate change: methodological considerations in predicting shifting population dynamics of infectious disease vectors. ISPRS Int J Geoinf 2013;2(3):645–64. doi: 10.3390/ijgi2030645.
[235] MacDonald AJ, McComb S, O'Neill C, Padgett KA, Larsen AE. Projected climate and land use change alter western blacklegged tick phenology, seasonal host-seeking suitability and human encounter risk in California. Glob Chang Biol 2020;26(10):5459–74. doi: 10.1111/gcb.15269.
[236] Ditsuwan T, Liabsuetrakul T, Chongsuvivatwong V, Thammapalo S, McNeil E. Assessing the spreading patterns of dengue infection and chikungunya fever outbreaks in lower southern thailand using a geographic information system. Ann Epidemiol 2011;21(4):253–61. doi: 10.1016/j.annepidem.2010.12.002.
[237] Metelmann S, Caminade C, Jones AE, Medlock JM, Baylis M, Morse AP. The UK's suitability for Aedes albopictus in current and future climates. J R Soc Interface 2019;16(152):20180761. doi: 10.1098/rsif.2018.0761.
[238] Campbell LP, Luther C, Moo-Llanes D, Ramsey JM, Danis-Lozano R, Peterson AT. Climate change influences on global distributions of dengue and chikungunya virus vectors. Phil Trans R Soc B 2015;370(1665):20140135. doi: 10.1098/rstb.2014.0135.
[239] Kraemer MUG, Reiner Jr RC, Brady OJ, Messina JP, Gilbert M, Pigott DM, et al. Past and future spread of the arbovirus vectors Aedes aegypti and Aedes albopictus. Nat Microbiol 2019;4(5):854–63. doi: 10.1038/s41564-019-0376-y.
[240] Liu-Helmersson J, Brännström Å, Sewe MO, Semenza JC, Rocklöv J. Estimating past, present, and future trends in the global distribution and abundance of the arbovirus vector aedes aegypti under climate change scenarios. Front Public Health 2019;7:148. doi: 10.3389/fpubh.2019.00148.
[241] Monaghan AJ, Sampson KM, Steinhoff DF, Ernst KC, Ebi KL, Jones B, et al. The potential impacts of 21st century climatic and population changes on human exposure to the virus vector mosquito Aedes aegypti. Clim Change 2018;146(3–4):487–500. doi: 10.1007/s10584-016-1679-0.
[242] Erguler K, Smith-Unna SE, Waldock J, Proestos Y, Christophides GK, Lelieveld J, et al. Large-Scale Modelling of the Environmentally-Driven Population Dynamics of Temperate Aedes albopictus (Skuse). PLoS ONE 2016;11(2):e0149282. doi: 10.1371/journal.pone.0149282.
[243] Dhimal M, Gautam I, Joshi HD, O'Hara RB, Ahrens B, Kuch U. Risk factors for the presence of chikungunya and dengue vectors (Aedes aegypti and Aedes albopictus), their altitudinal distribution and climatic determinants of their abundance in central Nepal. PLoS Negl Trop Dis 2015;9(3):e0003545. doi: 10.1371/journal.pntd.0003545.
[244] Rochlin I, Faraji A, Ninivaggi DV, Barker CM, Kilpatrick AM. Anthropogenic impacts on mosquito populations in North America over the past century. Nat Commun 2016;7:13604. doi: 10.1038/ncomms13604.
[245] Abdalgader T, Pedersen M, Ren D, Sun G, Zhang L. Trade-off between climatic and human population impacts on Aedes aegypti life history shapes its geographic distribution. J Theor Biol 2022;535:110987. doi: 10.1016/j.jtbi.2021.110987.
[246] Laporta GZ, Potter AM, Oliveira JFA, Bourke BP, Pecor DB, Linton YM. Global distribution of aedes aegypti and aedes albopictus in a climate change scenario of regional rivalry. Insects 2023;14(1). doi: 10.3390/insects14010049.
[247] Ryan SJ, Carlson CJ, Mordecai EA, Johnson LR. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLoS Negl Trop Dis 2018;13(3). doi: 10.1371/journal.pntd.0007213.
[248] Echeverry-Cárdenas E, López-Castañeda C, Carvajal-Castro JD, OA Aguirre-Obando. Potential geographic distribution of the tiger mosquito Aedes albopictus (Skuse, 1894) (Diptera: culicidae) in current and future conditions for Colombia. PLoS Negl Trop Dis 2021;15(5):e0008212. doi: 10.1371/journal.pntd.0008212.
[249] Portilla Cabrera CV, Selvaraj JJ. Geographic shifts in the bioclimatic suitability for Aedes aegypti under climate change scenarios in Colombia. Heliyon 2020;6(1): e03101. doi: 10.1016/j.heliyon.2019.e03101.
[250] Carreto C, Gutiérrez-Romero R, Rodríguez T. Climate-driven mosquito-borne viral suitability index: measuring risk transmission of dengue, chikungunya and Zika in Mexico. Int J Health Geogr 2022;21(1):15. doi: 10.1186/s12942-022-00317-0.
[251] Chowell G, Mizumoto K, Banda JM, Poccia S, Perrings C. Assessing the potential impact of vector-borne disease transmission following heavy rainfall events: a mathematical framework. Philos Trans R Soc Lond B Biol Sci 1775;374:20180272 2019. doi: 10.1098/rstb.2018.0272.
[252] Gorris ME, Cat LA, Zender CS, Treseder KK, Randerson JT. Coccidioidomycosis Dynamics in Relation to Climate in the Southwestern United States. Geohealth 2018;2(1):6–24. doi: 10.1002/2017GH000095.
[253] Head JR, Sondermeyer-Cooksey G, Heaney AK, Yu AT, Jones I, Bhattachan A, et al. Effects of precipitation, heat, and drought on incidence and expansion of coccidioidomycosis in western USA: a longitudinal surveillance study. The Lancet Planetary Health 2022;6(10):e793–803. doi: 10.1016/S2542-5196(22)00202-9.
[254] Shriber J, Conlon KC, Benedict K, McCotter OZ, Bell JE. Assessment of vulnerability to coccidioidomycosis in arizona and California. Int J Environ Res Public Health 2017;14(7). doi: 10.3390/ijerph14070680.
[255] Gorris ME, Treseder KK, Zender CS, Randerson JT. Expansion of coccidioidomycosis endemic regions in the united states in response to climate change. Geohealth 2019;3(10):308–27. doi: 10.1029/2019GH000209.
[256] Ocampo-Chavira P, Eaton-Gonzalez R, Riquelme M. Of Mice and Fungi: coccidioides spp. Distribution Models. J Fungi (Basel) 2020;6(4). doi: 10.3390/jof6040320.
[257] Gorris ME, Neumann JE, Kinney PL, Sheahan M, Sarofim MC. Economic valuation of coccidioidomycosis (Valley Fever) projections in the united states in response to climate change. Weather Clim Soc 2021;13(1):107–23. doi: 10.1175/wcas-D-20-0036.1.
[258] Anyamba A, Linthicum KJ, Small JL, Collins KM, Tucker CJ, Pak EW, et al. Climate teleconnections and recent patterns of human and animal disease outbreaks. PLoS Negl Trop Dis 2012;6(1). doi: 10.1371/journal.pntd.0001465.
[259] Tjaden NB, Suk JE, Fischer D, Thomas SM, Beierkuhnlein C, Semenza JC. Modelling the effects of global climate change on Chikungunya transmission in the 21 (st) century. Sci Rep 2017;7(1):3813. doi: 10.1038/s41598-017-03566-3.
[260] Tjaden NB, Cheng Y, Beierkuhnlein C, Thomas SM. Chikungunya beyond the tropics: where and when do we expect disease transmission in Europe? Viruses 2021;13(6). doi: 10.3390/v13061024.
[261] Ng V, Fazil A, Gachon P, Deuymes G, Radojevic M, Mascarenhas M, et al. Assessment of the probability of autochthonous transmission of chikungunya virus in Canada under recent and projected climate change. Environ Health Perspect 2017;125(6):067001. doi: 10.1289/EHP669.
[262] Fischer D, Thomas SM, Suk JE, Sudre B, Hess A, Tjaden NB, et al. Climate change effects on Chikungunya transmission in Europe: geospatial analysis of vector's climatic suitability and virus' temperature requirements. Int J Health Geogr 2013;12:51. doi: 10.1186/1476-072X-12-51.
[263] Oliveira SVD, Romero-Alvarez D, Martins TF, Santos JPD, Labruna MD, Gazeta GS, et al. Amblyomma ticks and future climate: range contraction due to climate warming. Acta Trop. 2017;176:340–8. doi: 10.1016/j.actatropica.2017.07.033.
[264] Raghavan RK, Goodin DG, Neises D, Anderson GA, Ganta RR. Hierarchical bayesian spatio-temporal analysis of climatic and socio-economic determinants of rocky mountain spotted fever. PLoS ONE 2016;11(3):e0150180. doi: 10.1371/journal.pone.0150180.
[265] Alkishe A, Peterson AT. Climate change influences on the geographic distributional potential of the spotted fever vectors Amblyomma maculatum and Dermacentor andersoni. PeerJ 2022;10:e13279. doi: 10.7717/peerj.13279.
[266] Chen Y, Gebert MJ, Faith SA, Dunn RR, Fierer N, Barberán A. Global patterns and climatic controls of dust-associated microbial communities. Microbiol Spectr 2021;9(2):e0144721. doi: 10.1128/Spectrum.01447-21.
[267] Cunze S, Glock G, Kochmann J, Klimpel S. Ticks on the move-climate change-induced range shifts of three tick species in Europe: current and future habitat suitability for Ixodes ricinus in comparison with Dermacentor reticulatus and Dermacentor marginatus. Parasitol Res 2022;121(8):2241–52. doi: 10.1007/s00436-022-07556-x.
[268] Cogliati M. Global warming impact on the expansion of fundamental niche of Cryptococcus gattii VGI in Europe. Environ Microbiol Rep 2021;13(3):375–83. doi: 10.1111/1758-2229.12945.
[269] Valencia-Marín BS, Gandica ID, Aguirre-Obando OA. The Mayaro virus and its potential epidemiological consequences in Colombia: an exploratory biomathematics analysis. Parasites Vect 2020;13(1):508. doi: 10.1186/s13071-020-04354-1.
[270] Celone M, Pecor DB, Potter A, Richardson A, Dunford J, Pollett S. An ecological niche model to predict the geographic distribution of Haemagogus janthinomys, Dyar, 1921 a yellow fever and Mayaro virus vector, in South America. PLoS Negl Trop Dis 2022;16(7). doi: 10.1371/journal.pntd.0010564.
[271] Lyth A, Holbrook NJ. Assessing an indirect health implication of a changing climate: ross River Virus in a temperate island state. Climate Risk Manag 2015;10:77–94. doi: 10.1016/j.crm.2015.06.004.
[272] Uusitalo R, Siljander M, Culverwell CL, Hendrickx G, Linden A, Dub T, et al. Predicting spatial patterns of sindbis virus (SINV) infection risk in finland using vector, host and environmental data. IJERPH 2021;18(13):7064. doi: 10.3390/ijerph18137064.
[273] Naish S, Mengersen K, Hu W, Tong S. Forecasting the future risk of barmah forest virus disease under climate change scenarios in queensland. Australia. PLoS One 2013;8(5):e62843. doi: 10.1371/journal.pone.0062843.
[274] MacDonald AJ. Abiotic and habitat drivers of tick vector abundance, diversity, phenology and human encounter risk in southern California. PLoS ONE 2018;13 (7):e0201665. doi: 10.1371/journal.pone.0201665.
[275] Kopsco HL, Gronemeyer P, Mateus-Pinilla N, Smith RL. Current and future habitat suitability models for four ticks of medical concern in illinois, USA. Insects 2023;14(3). doi: 10.3390/insects14030213.
[276] Shocket MS, Ryan SJ, Mordecai EA. Temperature explains broad patterns of Ross River virus transmission. Elife 2018;7. doi: 10.7554/eLife.37762.

[277] Fisman DN, Tuite AR, Brown KA. Impact of El Niño Southern Oscillation on infectious disease hospitalization risk in the United States. Proc Natl Acad Sci USA 2016;113(51):14589–94. doi: 10.1073/pnas.1604980113.

[278] Lerner A, Matthias T. The world incidence and prevalence of autoimmune diseases is increasing. Int J Celiac Dis 2015;3:151–5. doi: 10.12691/ijcd-3-4-8.

[279] Fatoye F, Gebrye T, Svenson LW. Real-world incidence and prevalence of systemic lupus erythematosus in Alberta, Canada. Rheumatol Int 2018;38:1721–6. doi: 10.1007/s00296-018-4091-4.

[280] Conrad N, Misra S, Verbakel JY, Verbeke G, Molenberghs G, Taylor P, et al. Incidence, prevalence, and co-occurrence of autoimmune disorders over time and by age, sex, and socioeconomic status: a population-based cohort study of 22 million individuals in the UK. The Lancet 2023;401(10391):1878–90. doi: 10.1016/S0140-6736(23)00457-9.

[281] Parodis I, Lanata C, Nikolopoulos D, Blazer A, Yazdany J. Reframing health disparities in SLE: a critical reassessment of racial and ethnic differences in lupus disease outcomes. Best Pract Res Clin Rheumatol 2023:1018. doi: 10.1016/j.berh.2023.101894.

[282] Yelin E, Trupin L, Yazdany J. A prospective study of the impact of current poverty, history of poverty, and exiting poverty on accumulation of disease damage in systemic lupus erythematosus. Arthritis Rheumatol 2017;69(8):1612–22 Epub 2017 Jul 5. doi: 10.1002/art.40134.

[283] Yazdany J, Gillis JZ, Trupin L, Katz P, Panopalis P, Criswell LA, Yelin E. Association of socioeconomic and demographic factors with utilization of rheumatology subspecialty care in systemic lupus erythematosus. Arthritis Rheumatol 2007;57(4):593–600. doi: 10.1002/art.22674.

[284] Ciofoaia EI, Pillarisetty A, Constantinescu F. Health disparities in rheumatoid arthritis. Ther Adv Musculoskelet Dis 2022;14 1759720X221137127eCollection 2022. doi: 10.1177/1759720X221137127.

[285] 3 Aguirre A, Izadi Z, Trupin L, Barbour KE, Greenlund KJ, Katz P, Lanata C, Criswell L, Dall'Era M, Yazdany J. Race, ethnicity, and disparities in the risk of end-organ lupus manifestations following a systemic lupus erythematosus diagnosis in a multiethnic cohort. Arthritis Care Res (Hoboken) 2023;75(1):34–43. doi: 10.1002/acr.24892.

[286] Parodis I, Lanata C, Nikolopoulos D, Blazer A, Yazdany J. Reframing health disparities in SLE: a critical reassessment of racial and ethnic differences in lupus disease outcomes. Best Pract Res Clin Rheumatol 2023:101894 Online ahead of print. doi: 10.1016/j.berh.2023.101894.

[287] Gianfrancesco MA, Dall'Era M, Murphy LB, Helmick CG, Li J, Rush S, et al. Mortality among minority populations with systemic lupus erythematosus, including asian and hispanic/latino persons - California, 2007-2017. MMWR Morb Mortal Wkly Rep 2021;70(7):236–9. doi: 10.15585/mmwr.mm7007a2.

[288] Ammann P, Dietler D, Winkler MS. Health impact assessment and climate change: a scoping review. J Climate Change Health 2021;3:100045. doi: 10.1016/j.joclim.2021.10004.

[289] Törnqvist H, Mills NL, Gonzalez M, Miller MR, Robinson SD, Megson IL, et al. Persistent endothelial dysfunction in humans after diesel exhaust inhalation. Am J Respir Crit Care Med 2007;176(4):395–400. doi: 10.1164/rccm.200606-872OC.

[290] Sun G, Hazlewood G, Bernatsky S, Kaplan GG, Eksteen B, Barnabe C. Association between air pollution and the development of rheumatic disease: a systematic review. Int J Rheumatol 2016;5356307. doi: 10.1155/2016/5356307.

[291] Pan Y, Fang Y, Chen Y, et al. Associations between particulate matter air pollutants and hospitalization risk for systemic lupus erythematosus: a time-series study from Xi'an, China. Environ Geochem Health 2023;45:3317–30. doi: 10.1007/s10653-022-01409-3.

[292] Radner Helga. Chapter 2 - Comorbidities in patients with rheumatic disease, handbook of systemic autoimmune diseases 2018;15:15–37. doi: 10.1016/B978-0-444-63887-8.00002-5.

[293] Liu J., Varghese B.M., Hansen A., Zhang Y., Driscoll T., Morgan G., Dear K., Gourley M., Capon A., Bi P. Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. Lancet Planet Health 202;6(6):e484−95. https://doi.org/10.1016/S2542-5196(22)00117-6

[294] Owino V, Kumwenda C, Ekesa B, Parker ME, Ewoldt L, Roos N, et al. The impact of climate change on food systems, diet quality, nutrition, and health outcomes: a narrative review. Frontiers in Climate 2022;4:1–10. doi: 10.3389/fclim.2022.941842.

[295] Mora C, McKenzie T, Gaw IM, Dean JM, von Hammerstein H, Knudson TA, et al. Over half of known human pathogenic diseases can be aggravated by climate change. Nat Clim Chang 2022;12:869–75. doi: 10.1038/s41558-022-01426-1.

[296] Amaral JK, Bilsborrow JB, Schoen RT. Chronic chikungunya arthritis and rheumatoid arthritis: what they have in common. Am. J. Med. 2020;133(3):e91–7. doi: 10.1016/j.amjmed.2019.10.005.

[297] Lochhead RB, Strle K, Arvikar SL, Weis JJ, Steere AC. Lyme arthritis: linking infection, inflammation and autoimmunity. Nat Rev Rheumatol 2021;17(8):449–61. doi: 10.1038/s41584-021-00648-5.

[298] Chen YW, Hsieh TY, Lin CH, Chen HM, Lin CC, Chen HH. Association between a history of dengue fever and the risk of systemic autoimmune rheumatic diseases: a nationwide, population-based case-control study. Front Med (Lausanne) 2021;3(8):738291 2021. doi: 10.3389/fmed.2021.738291.eCollection.

[299] Finan PH, Zautra AJ. Rheumatoid arthritis: stress affects rheumatoid arthritis, but via what mechanisms? Nat Rev Rheumatol 2013;9(10):569–70. doi: 10.1038/nrrheum.2013.139.

[300] Kurth C, Pihkala P. Eco-anxiety: what it is and why it matters. Front Psychol 2022;23(13):981814 2022. doi: 10.3389/fpsyg.2022.981814.eCollection.

[301] Gremese E, Tolusso B, Gigante MR, Ferraccioli G. Obesity as a risk and severity factor in rheumatic diseases (autoimmune chronic inflammatory diseases). Front Immunol 2014;5:576. doi: 10.3389/fimmu.2014.00576.

[302] Sakkas LI, Bogdanos DP. Infections as a cause of autoimmune rheumatic diseases. Autoimmun Highlights 2016;7:13. doi: 10.1007/s13317-016-0086-x.