

Understanding the Relationships Between Physical Activity and Climate Change: An Umbrella Review

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Background: Physical activity is crucial for maintaining health and preventing chronic diseases. However, climate conditions can impact physical activity patterns, and conversely, physical activity can impact climate change. This umbrella review aims to summarize the existing evidence regarding the relationships between physical activity and climate change, as revealed in previous reviews. **Methods:** Systematic reviews and meta-analyses were analyzed. Searches were conducted across GreenFILE, PubMed, and Web of Science databases for peer-reviewed articles published in English. A 2-stage independent screening process was conducted, and methodological quality was assessed using the JBI framework. Standardized data extraction methods were then applied. **Results:** Out of 1292 articles retrieved, 7 met all eligibility criteria and were included in the review. Three articles examined physical activity as a primary exposure, 3 focused on the impacts of climate change, and one considered both physical activity and climate change as primary exposures. **Conclusions:** Findings reveal an interplay between climate change and physical activity. While rising temperatures may prompt outdoor activities up to a certain temperature threshold, air pollution and extreme heat can have harmful effects. Active transportation and improved logistics around large-scale sporting events can mitigate climate change by reducing greenhouse gas emissions, but transportation systems linked to sports venues may increase emissions. Research on the reciprocal relationship between climate change and physical activity domains, and integrating the community into climate discussions, is crucial for equity, especially for marginalized communities. Incorporating climate adaptation and mitigation strategies in physical activity infrastructure to minimize environmental impacts is critical.

An abundant body of evidence over the past several decades has demonstrated the myriad benefits to human health resulting from various forms, volumes, and intensities of physical activity.¹ Those benefits range from cardiovascular to mental health²⁻⁵ and include significant population health impacts such as lower premature mortality⁶ and

reduced costs to health care systems in both high-income and middle-low-income countries.⁷ Despite raised awareness of these health impacts and increased capacity in physical activity research, policy, and practice around the globe,⁸⁻¹⁰ inactivity remains a major global health concern, particularly among the most vulnerable populations within and between countries.¹¹

At the same time, research on climate sciences has produced overwhelming evidence that human-induced emissions of greenhouse gases are clear drivers of global warming, triggering extensive changes in the atmosphere, oceans, frozen regions, and living ecosystems.¹² Global warming and climate change more generally have prompted an increase in extreme weather events worldwide with dramatic, negative impacts on human communities and entire ecosystems.¹² The multiple negative health impacts in the context of climate change include the expansion of vector-borne infectious diseases; cardiovascular risks related to heat;¹³ threatened access^{14,15} to housing, health resources, and healthy food sources¹⁶; and negative mental health effects.¹⁷⁻²⁰ Studies indicate that climate-related disasters such as hurricanes, floods, and wildfires induce prolonged psychological distress,¹⁷ and that higher global temperatures are associated with poorer sleep quality.²¹ Moreover, the uncertainty and anticipation of future climate-related crises contribute significantly to widespread climate anxiety, depression, and stress,¹⁸ particularly affecting communities deeply connected to their natural surroundings.¹⁹ Similarly to physical activity, despite increased awareness about the planetary and human health impacts of climate change and the need for urgent actions, for the most part scalable and sustainable solutions have not yet been implemented.²²

As societies grapple with the adverse consequences of climate change, understanding the intricate relationship between climate change and physical activity is crucial for developing sustainable strategies to promote both human and environmental well-being. This relationship is bidirectional, with climate change influencing physical activity behaviors and opportunities, and vice versa. Climate change is closely intertwined with whether people have safe, equitable opportunities to engage in physical activity.²³ Warmer temperatures in some regions might prompt people with personal vehicles to drive instead of walking or cycling and exercising in indoor air-conditioned spaces instead of being active outdoors. Conversely, physical activity, particularly active travel like walking and cycling, can mitigate climate change by reducing carbon emissions, curbing air pollution, and conserving energy.²⁴ This perspective aligns with the concept of sustainable physical activity,²⁵ which considers the environmental impact of various types of physical activity, such as active transportation, local community activities, and basic daily tasks with minimal equipment. Moreover, engaging in outdoor activities fosters a deeper connection with nature, potentially nurturing a sense of environmental responsibility and advocacy for preserving vital ecosystems.²³ However, people who commute or travel outdoors by

necessity—that is, without access to personal vehicles, or as part of their work—may be subject to disproportionate health risks from extreme heat or other weather events precipitated by a warming global climate.

Physical activity also has environmental implications. For example, engaging in indoor leisure-time physical activities like sport or exercise can lead to adverse environmental consequences, as indoor exercise facilities may increase energy demand for heating and cooling. Additionally, outdoor sports and recreation that involve motorized travel further exacerbate climate change²⁶ through high CO₂ emissions²⁷ and the disruption of ecosystems and wildlife habitats.²⁸ Addressing these bidirectional influences is essential for promoting both human health and environmental sustainability.

Over the last few years, a growing body of literature has explored the connections between climate change and physical activity, resulting in numerous systematic reviews and meta-analyses^{29–32} on this topic. However, these reviews have often focused on specific domains of physical activity (eg, active transport) or selected elements of climate change (eg, greenhouse gas emissions, rising temperatures, and others). To date, there is no comprehensive summary of the existing evidence that gathers information from studies across disciplines that describe the overall relationships, gaps, and practical recommendations related to climate change and physical activity.

Understanding and alleviating the effects of climate change on physical activity behaviors is necessary for human health.³³ While encouraging physical activity for health benefits is essential, prioritizing activities that minimize negative environmental impacts is equally imperative.²³ Additionally, it is essential to consider how climate-sensitive exposures can influence physical activity behaviors. In this context, it is crucial to understand the complex connections between climate change and physical activity, and to advocate for responsible and sustainable practices that recognize the interdependence of human well-being and planetary health.^{27,33} Umbrella reviews, which summarize and compare individual reviews on a broad research question to establish a high level of evidence, can enable the development of practical guidelines and policy recommendations for complex questions³⁴ like climate change and physical activity. This study aimed to summarize the existing evidence regarding the relationships between physical activity and climate change, as revealed in previous reviews. Nonetheless, the bidirectional nature of the relationship between climate change and physical activity has been understudied. By focusing on existing systematic reviews and meta-analyses, we can provide a comprehensive understanding of the interplay between physical activity and climate change, thereby informing interventions and policies for researchers, policymakers, and public health officials.

Methods

There has been significant growth in literature exploring the connection between climate change and physical activity, resulting in numerous systematic reviews and meta-analyses. However, there is a notable lack of umbrella reviews, which synthesize findings from existing reviews to gather comprehensive information on relationships, gaps, and practical recommendations.^{34,35} We conducted an umbrella review based on previously published reviews and meta-analyses on the relationship between physical activity and climate change. We followed Joanna Briggs Institute (JBI) Umbrella Review guidelines,³⁴ a widely adopted framework for conducting and reporting an Umbrella Review. This review is registered in the Prospective Register of Systematic Reviews platform (ID CRD42024497127).

Inclusion Criteria

Table 1 describes the inclusion and exclusion criteria utilized in this review. Studies were included if they satisfied the following criteria: (1) Document type: peer-reviewed journal articles; (2) Study design: systematic reviews or meta-analyses; (3) Language: articles published in English; (4) Exposure: studies explicitly naming climate change or physical activity as exposure variables, or exploring changes in temperature, precipitation, extreme weather events, or other climate-related factors influencing physical activity patterns, or considering physical activity as a variable capable of impacting climate change positively or negatively; (5) Outcome: investigations into the impacts of climate change on various aspects of physical activity or the effects of physical activity on climate change; and (6) Core concepts: studies examining the relationships between physical activity and climate change, the impact and or associations between climate change policies on physical activity, or vice versa. To ensure rigorous application of criteria 4–6, we carefully evaluated each study’s objectives and scope. For criterion 4, we included studies directly addressing climate change variables and their influence on physical activity patterns or vice versa. For criterion 5, we focused on studies providing clear evidence of the impacts of climate change on physical activity or vice versa. For criterion 6, we included studies exploring the relationships between climate change and physical activity, considering both aspects in their analysis. We imposed no restrictions regarding the year of publication, population studied, or study setting.

Table 1

Inclusion and Exclusion Criteria

	Inclusion criteria	Exclusion criteria
Document type	All peer-reviewed journal articles	Editorials, letters to the editor, opinion papers, magazine articles, books and book chapters, book reviews, poster and conference abstracts, reports, study protocols, dissertations, and research-based commentaries
Study design	Systematic reviews and meta-analyses	Reviews that incorporate theoretical studies or text and opinion as their primary source of evidence or any other review that is not considered a systematic review or meta-analysis
Timeframe	No time restriction	No time restriction
Language	English	Other languages that are not English
Population	No population restriction	No population restriction
Setting	No setting restriction	No setting restriction
Exposure	<ul style="list-style-type: none"> - Explicitly have climate change or physical activity as exposure variables - Consider changes in temperature, precipitation, extreme weather events, or other climate-related 	<ul style="list-style-type: none"> - Do not explicitly consider climate change or physical activity as exposure variables - Solely focuses on climate change without exploring its connection with physical activity

	Inclusion criteria	Exclusion criteria
	<p>factors that might affect patterns of physical activity</p> <ul style="list-style-type: none"> - Consider the practice of physical activity as a variable capable of influencing positively or negatively climate change 	<ul style="list-style-type: none"> - Solely focuses on physical activity without exploring its connection with climate change
Outcome	<ul style="list-style-type: none"> - Impacts of climate change on all domains of physical activity - Impacts of the practice of physical activity on climate change 	<ul style="list-style-type: none"> - Do not explicitly investigate the relationship between physical activity and climate change - Solely focused on physical activity outcomes without considering the impact of climate change - Solely focused on climate change outcomes without considering the impact of physical activity
Core concepts	<ul style="list-style-type: none"> - Relationships between physical activity and climate change - Impact of climate change policies on physical activity or vice versa 	<ul style="list-style-type: none"> - Do not address the relationship between physical activity and climate change - Discusses physical activity or climate change but does not integrate both concepts into the analysis

Search Strategy

The search strategy specifically encompassed systematic reviews and meta-analyses addressing the relationships between physical activity and climate change. The searches were conducted in the first week of January 2024 in 3 electronic databases: GreenFILE via EBSCO, PubMed, and Web of Science. The syntax included possible

combinations of keywords connected by Boolean operators from 4 groups: climate change, physical activity, systematic review, and meta-analysis (Table 2).

Table 2

Search Strategy

Topics	Climate change	Physical activity	Systematic review	Meta-analysis
Keywords	climat* change*	physical activit*	systematic review*	meta analysis
	global warming	exercis*		metaanalysis
	CO ₂	sport*		metanalysis
	air pollution	active transport		met analysis
	heat island	cycling		metasynthesis
	sea level rise	running		meta synthesis
	sea level change*	physical conditioning		
	weather anomalies	bicycling		
	weather variabilities	walking		

Topics	Climate change	Physical activity	Systematic review	Meta-analysis
	heat wave*	jogging		
	weather intensities			
	flood*			
	drought			
	snowfall			
	greenhouse gas*			
	wildfire			

Syntax in Web of Science: ((ALL=("climat* change*" OR "global warming" OR "sea level rise" OR "sea level change*" OR "weather anomalies" OR "weather variabilities" OR "heat wave*" OR "weather intensities" OR "flood*" OR "drought" OR "snowfall" OR "greenhouse gas*" OR "wildfire" OR "air pollution" OR "heat island" OR "CO₂")) AND ALL=("physical activit*" OR "exercis*" OR "sport*" OR "physical conditioning" OR "running" OR "bicycling" OR "walking" OR "jogging" OR "active transport" OR "cycling")) AND ALL=("meta analysis" OR "metaanalysis" OR "metanalysis" OR "met analysis" OR "metasynthesis" OR "meta synthesis" OR "systematic review*").

Syntax for PubMed and GreenFILE: (("climate change*" OR "global warming" OR "sea level rise" OR "sea level change*" OR "weather anomalies" OR "weather variabilities" OR "heat wave*" OR "weather intensities" OR "flood*" OR "drought" OR "snowfall" OR "greenhouse gas*" OR "wildfire" OR "air pollution" OR "heat island" OR "CO₂") AND ("physical activit*" OR "exercis*" OR "sport*" OR "physical conditioning" OR "running" OR "bicycling" OR "walking" OR "jogging" OR "active transport" OR "cycling")) AND ("meta analysis" OR "metaanalysis" OR "metanalysis" OR "met analysis" OR "metasynthesis" OR "meta synthesis" OR "systematic review*").

Study Screening and Selection

The initial stage of study screening involved assessing keywords located within the titles and abstracts of the retrieved publications. The second stage consisted of a full-text examination of studies selected in the first stage which met the inclusion criteria. Both stages were conducted by 2 reviewers independently and blindly. Any disagreements were solved by the decision of a third reviewer. Collaborative result filtering was facilitated using Rayyan,³⁶ an online application that supports researchers in systematic review methodology and meta-analysis projects.

Assessment of Methodological Quality

All eligible studies underwent a methodological quality assessment using the standard JBI critical appraisal instrument for Systematic Reviews and Research Syntheses (Appendix 1).³⁷ The instrument only yields a final decision regarding the overall appraisal to either include or exclude an article. Two independent reviewers (Franco Silva and Favarão Leão) conducted the critical appraisal for each selected research synthesis. The reviewers carried out this process independently, with no access to each other's assessments, and comparisons were made only after both reviewers completed the entire appraisal of the articles. Any instances of disagreement were resolved by consulting with a third reviewer (Siqueira Reis).

Data Extraction and Summary

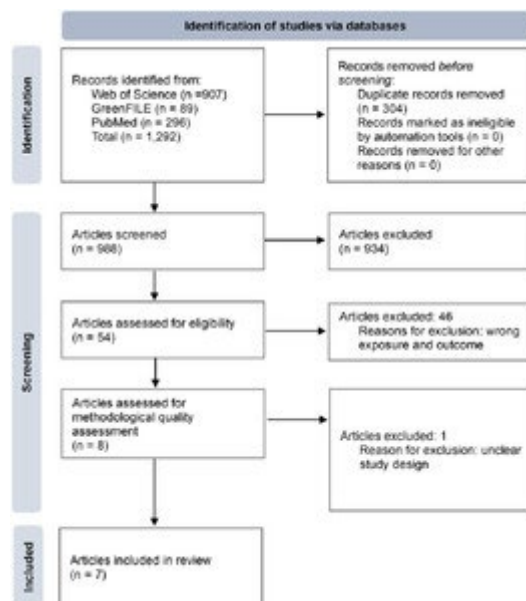
Data extraction followed the standardized JBI data extraction tools, with additional information included as deemed relevant by the reviewers (Appendix 2). Before the official launch of the extraction process, a piloting phase was conducted with 2 reviewers. This step aimed to enhance consistency and increase the probability of adequately identifying and detailing relevant results, ensuring their suitability for reporting in this umbrella review. After the piloting phase, each reviewer independently carried out the final data extraction. This process comprehensively listed descriptive information about the articles as well as outcomes, exposures, and core concepts related to climate change and physical activity, including policy. This umbrella review exclusively utilized data published in the included studies, acknowledging the potential for any missing data or information.

The criteria for the data summary did not impose a minimum number of included and analyzed studies. The formal method for analyzing and summarizing the results exclusively relied on statistical descriptions. The outcomes of quantitative data were represented through tabular formats to display an overall number of studies and the heterogeneity of the results. Similarly, the outcomes of qualitative information were synthesized and tabulated, ensuring that each finding was accompanied by adequate contextual information (eg, publication information and core themes and concepts) for clear understanding. The summary also indicated any instances where original research

studies were included in multiple syntheses. The reporting of the umbrella review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses³⁸ and JBI Umbrella Review guidelines.³⁴

Results

Searches conducted in PubMed, Web of Science, and GreenFILE resulted in a combined total of 1292 studies. After eliminating duplicates (n = 304), 988 records underwent screening based on title and abstract, resulting in the exclusion of 934 records. Subsequently, 54 articles proceeded to full-text screening. Out of these, 46 were excluded due to unmet exposure and outcome criteria. Several studies concentrated solely on the impact of climate change on the environment or delved into chemical observations, such as the soil carbon and nitrogen cycle. Others primarily addressed the health repercussions of climate change, specifically highlighting issues like heart and circulatory diseases resulting from air pollution, with physical activity considerations being only peripheral. Among the remaining 8 articles, one was excluded during the quality assessment phase due to insufficient clarity regarding study design. Ultimately, 7 articles satisfactorily addressed all inquiries outlined in the JBI critical appraisal instrument,³⁷ demonstrating complete methodological quality. Consequently, these articles were included in the review (Figure 1).



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Figure 1

—Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of the reviewing process.

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Table 3 provides a comprehensive overview of the characteristics of the included studies. Among the 7 studies, 5 were systematic reviews and 2 were systematic reviews followed by a meta-analysis. Three studies were published between 2014 and 2018, while the remaining 4 were published between 2019 and 2023. Three of the studies focused on physical activity as the exposure of interest, 3 on climate change, and one considered both physical activity and climate change as primary exposures. Outcomes varied: one study explored the impact of physical activity on climate change,³⁹ 3 investigated the impact of climate change on physical activity,^{30,40,41} and the remaining 3 examined the reciprocal impacts of climate change on physical activity and vice versa.^{29,31,42} Author affiliations in all articles were exclusively from North America, Europe, Asia, or Oceania. No authors of the 7 articles had affiliations with institutions from South America or Africa. The studies included in this review assessed a total of 270 nonmutually exclusive articles. The search time frame ranged from January 1992 to July 2022. One of the reviews focused on a specific geographical location,⁴⁰ while the rest covered various locations, with 81.5% originating from the Global North and 18.5% from the Global South.

Table 3

Basic Characteristics of the Included Studies (N = 7)

Variables	Categories	n	%
Type of study	Systematic review ^{29-31,40,42}	5	71.42
	Meta-analysis	0	0.00
	Both ^{39,41}	2	28.58
Year of publication	2014–2018 ^{31,41,42}	3	42.85
	2019–2023 ^{29,30,39,40}	4	57.15
Exposure	Physical activity ^{31,39,42}	3	42.85

Variables	Categories	n	%
	Climate change ^{30,40,41}	3	42.85
	Both ²⁹	1	14.30
Outcome	Impacts of physical activity on climate change ³⁹	1	14.30
	Impacts of climate change on physical activity ^{30,40,41}	3	42.85
	Impacts of physical activity on climate change and vice versa ^{29,31,42}	3	42.85

Table 4 summarizes the key findings reported in the studies included in this review. Wilby et al³⁹ examined the impacts of physical activity on climate change and underscored how improved logistics around large-scale sporting events—such as optimizing food supply chains, improving waste management, investing in renewable energy projects, enhancing management and control systems for sports facilities, and optimizing transportation for competitors and spectators—can significantly influence global climate action. They identified these strategies as pivotal in reducing carbon footprints associated with sports events. Additionally, the authors discussed the benefits of promoting low-carbon travel options, vehicle-sharing, and discouraging long-distance air travel by downsizing and rotating sport events among the same cities to mitigate carbon emissions related to these events. This study also highlighted a growing recognition of legal accountability for climate impacts within this sector, emphasizing the significant role sports can play as either a mitigating or adaptive factor. Decisions made within the sports sector can have both positive and negative implications for climate action, reinforcing the need for careful consideration of sustainability and minimal environmental impact, especially for major events like the Olympic Games. Moreover, the authors identified knowledge gaps concerning carbon accounting tools and indicators for smaller sports clubs and participants, as well as co-benefits and trade-offs between mitigation and adaptation efforts in sports, including venues, equipment, facilities, geopolitical influence, and potential climate change litigation against hosts or sponsors of carbon-intensive events.³⁹

Table 4

Main Findings From the Studies Included in the Review

Studies (n)	Exposure	Outcome	Authors	Included articles per study, n	Main findings
1	Physical activity	Impacts of physical activity on climate change	Wilby et al ³⁹	116	1. Physical activity, being represented by the sport sector, can play a significant role in driving climate action on a global scale, as there is a growing recognition of legal accountability for climate impacts within the sports sector. There is a need for affordable and easy-to-use tools, standard guidance, and indicators for measuring carbon footprints

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					within the sports sector.
					<p>2. There are potential co-benefits and tradeoffs between mitigation and adaptation efforts in sports, particularly regarding logistics, venue selection, sports equipment, and facilities. This suggests that decisions made within the sports sector regarding climate action may have both positive and negative implications that need to be carefully</p>

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					<p>considered. Improved logistics around large-scale sporting events—such as food supply chains, distribution points, and transport optimization—can be strategies to influence global climate action, through the reduction of carbon footprints in sports events.</p>
					<p>3. Suggests a shift in perspective toward a new Olympic motto that emphasizes slower, closer, and lighter footprints,</p>

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					highlighting the need for a more sustainable approach to sports in the face of climate change.
2	Physical activity	Impacts of climate change on physical activity and vice versa	Quam et al ³¹	31	1. Physical activity, being represented by active transport, is relevant in achieving optimal health and reduction in greenhouse gas emissions. The infrastructure for active transport is an effective mitigation policy.

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					<p>2. The most suitable mitigation scenario for communities is determined by their cultural and geographical contexts.</p>
			Shaw et al ⁴²	22	<p>3. Interventions have a low impact on active transportation increase, but this impact reduces CO₂ emissions and vehicle use.</p>
					<p>4. Implementing transportation mitigation policies that improve health benefits and</p>

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					<p>reduce inequalities is challenging but necessary, especially given the increasing rate of climate change.</p>
3	Climate change	Impacts of climate change on physical activity	An et al ³⁰	10	<p>1. Overall, global warming was found to be associated with a net increase in active commuting and leisure-time physical activity. However, this trend might diminish once a certain temperature threshold is reached.</p>
					<p>2. The connections</p>

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					<p>between global warming, active commuting, and leisure-time physical activity vary based on the timeframe, geographical location, and cultural context.</p>
			An et al ⁴⁰	10	<p>3. A decrease in overall air quality and an increase in PM2.5 concentration have been linked to a reduction in the daily or weekly duration of outdoor leisure time and transportation-related physical</p>

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
					activities, such as walking, among Chinese residents.
			An et al ⁴¹	7	4. Air pollution is negatively associated with physical activity and positively associated with leisure-time physical inactivity. There is a need to evaluate the impact of air pollution on physical activity especially in heavily polluted countries.
1	Physical activity and	Impacts of climate change	Bernard et al ²⁹	74	1. There is a negative impact of air

Studies (n)	Exposure	Outcomes	Authors	Included articles per study, n	Main findings
	climate change	on physical activity and vice versa			<p>pollution, extreme temperatures, and natural disasters on levels of physical activity, which received a broad definition, including different domains such as “travel PA,” “travel + leisure PA,” and “outdoor PA.” It was found that occupational physical activity and active travel are particularly at risk during heat waves or pollution alerts, especially for adults living in the most</p>

Studies (n)	Exposure	Outcome	Authors	Included articles per study, n	Main findings
					deprived areas.
					2. The sports and physical activity communities can play a significant role in mitigating the impacts in postnatural disaster contexts. However, it's important to note that transportation associated with sports practices also contributes to greenhouse gas emissions

Quam et al³¹ and Shaw et al⁴² conducted research that delved into the impacts of physical activity on climate change, while simultaneously verifying the health outcomes stemming from both physical activity and the reduction of greenhouse gas emissions. They concluded that active transportation activities like walking and biking play a crucial role in decreasing greenhouse gas emissions and that air quality is considered a health determinant. Quam et al³¹ highlighted that active transportation, considered a “greener” mode of travel, emits nearly zero greenhouse gases per kilometer traveled.

They arrived at these estimations using the Simple Interactive Models for better air quality (SIM-air) tool developed by UrbanEmissions.info and the COPERT4 software from the European Environment Agency. Shaw et al⁴² stated that while interventions aimed at promoting active transportation behaviors may initially have a modest impact, they significantly reduce vehicle use and thus CO₂ emissions over time. However, the suitability of mitigation strategies varies depending on cultural and geographical contexts. These studies underscore the effectiveness of establishing infrastructure for active transportation as a valuable mitigation strategy. This involves considerations such as incorporating low-emission vehicles and enhancing public transportation systems. They advocate for the implementation of transportation policies that not only promote environmental sustainability but also enhance public health outcomes and address societal inequalities. This need is particularly urgent considering the escalating rate of climate change.

In investigating the impacts of climate change on physical activity, An et al³⁰ revealed that rising temperatures are linked to a net increase in active commuting and leisure-time physical activity worldwide. However, this trend may decline once a specific temperature threshold is surpassed.³⁰ The relationship between global warming, active commuting, and leisure-time physical activity is influenced by factors such as seasonality, geographical location, and cultural context.²⁶ For example, individuals residing in the northern temperate zone, such as the US Arctic (Alaska), may not experience the same degree of impact as those living in coastal regions, islands, or the desert Southwest.⁴³ Another instance underscores the heightened vulnerability of indigenous and island communities to sea level rise in contrast to those living farther inland. On the other hand, An et al⁴⁰ and An et al⁴¹ found that deteriorating air quality such as higher levels of PM_{2.5}, which can be co-emitted with greenhouse gas emissions, have been associated with reduced regular outdoor physical activity⁴⁰ and increased leisure-time physical inactivity.⁴¹ This includes walking for leisure as well as transportation, as evidenced in China where air pollution significantly dissuades individuals from choosing bicycles as a mode of commuting.^{40,44} Additionally, during periods of poor air quality warnings, it's generally advised to refrain from outdoor activities,⁴⁰ further affecting transportation choices. This highlights the need to evaluate the impact of air pollution on physical activity, particularly in heavily polluted countries.⁴¹

Finally, Bernard et al²⁹ assessed both climate change and physical activity as exposures and examined their mutual effects. This study found that air pollution, extreme temperatures, and natural disasters have a detrimental effect on the levels of physical activity, especially among adults with chronic diseases, higher body mass index, and older adults. The authors adopted a broad definition of physical activity, including its different domains such as "travel PA," "travel + leisure PA," and "outdoor PA," and found that occupational physical activity and active travel are particularly at-risk during heat

waves or pollution alerts, especially for adults living in the most deprived areas.²⁹ On the other hand, the study revealed that sports and physical activity communities can significantly mitigate postnatural disaster effects by offering direct assistance to communities (such as cargo-bicycles) or aiding in managing postdisaster stress. However, it is crucial to acknowledge that transportation associated with sporting events also contributes to greenhouse gas emissions. For instance, attending soccer matches involves travel that adds to overall emissions. Additionally, this study found that the relationship between climate change and physical activity has global consequences, with physical activity exhibiting both mitigating and amplifying effects on climate change.

The results highlight the intricate relationships between various aspects of physical activity and climate change, as illustrated in Figure 2. Physical activity, such as active transportation and improved logistics around large-scale sporting events, can mitigate the impacts of climate change by reducing greenhouse gas emissions and mitigating postnatural disasters. However, transportation associated with sporting events can have adverse environmental effects, leading to increased emissions of greenhouse gases. Additionally, the influence of climate change on levels of physical activity can vary significantly. While rising temperatures, up to a certain threshold, may increase leisure-time physical activity and active transportation, factors like air pollution and extreme temperatures can decrease physical activity, especially outdoor pursuits, due to health concerns. Overall, physical activity can play a positive role in mitigating climate change by serving as an adaptive factor. The dynamics of these relationships can be influenced by contextual factors such as cultural, economic, and geographical considerations.

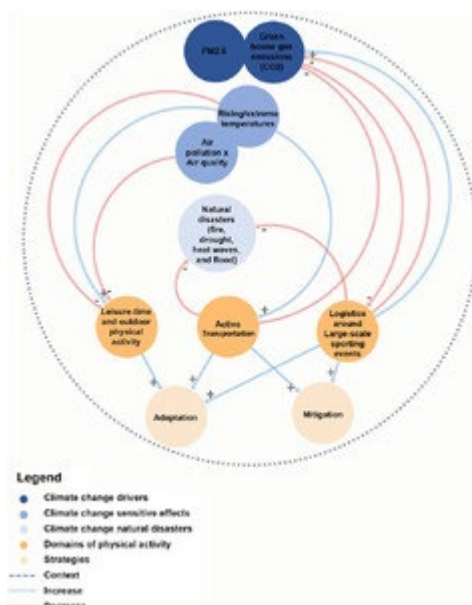


Figure 2

—The intricate relationships between physical activity and climate change. (Color figure online).

Discussion

This umbrella review systematically synthesized the scientific evidence examining the relationship between climate change and physical activity. Our thorough and up-to-date search yielded 7 systematic reviews. Overall, our findings provide an update and confirm the multifaceted nature of the relationship between climate change and physical activity, with positive and negative outcomes varying by the type and domain of physical activity (eg, active transportation, sports, leisure-time, or outdoor physical activities) and by climate change drivers and sensitive effects (eg, greenhouse gas emissions vs natural disasters vs rising temperatures vs air pollution). Contextual factors have been identified as critical to understanding the bidirectional nature of the relationship between climate change and physical activity, including the specific geographic (eg, coastal areas, urbanity, or rurality); cultural (eg, indigenous communities, island populations, or ethnic enclaves); and socioeconomic (eg, low- vs high-income populations) characteristics of communities and populations. Understanding the role of these contextual factors is critical when considering equitable, just, and safe strategies to promote physical activity in a changing climate. Individual studies have noted the bidirectional nature of this equity question from the perspective of physical activity and climate change. However, simultaneous testing of these interactions remains unexplored, highlighting gaps, and opportunities to reimagine and improve methods to study the effects and outcomes of climate change on physical activity at scale.

We observed that studies that analyzed the impacts of climate change on physical activity^{30,40,41} found 2 climate change effects: rising temperature and air pollution. Each of these factors yields distinct outcomes for physical activity. In the context of rising temperature, there is a potential positive impact, as individuals are more inclined to engage in outdoor exercise when the weather is warmer until a certain temperature threshold is reached.³⁰ However, for air pollution, the reverse effect is observed. Exposure to air pollution can deter individuals from exercising in their own environments due to health concerns.^{40,41} Tainio et al⁴⁵ suggest that high levels of air pollution can discourage individuals from engaging in outdoor physical activity, particularly active travel such as cycling and walking, due to concerns about the negative health consequences of pollution exposure. Additionally, air pollution and increasing temperatures are closely linked to natural disasters such as hurricanes, floods, and wildfires, which have shown significant and irreversible impacts on physical and mental health.⁴⁶ The destruction of parks, recreational facilities, and active transportation routes disrupts established routines and poses enduring challenges in reconstructing supportive environments for physical activity. This highlights the need for

adaptive strategies to ensure continued access to safe physical activity opportunities in the face of climate change effects.

Our review underscores the complexity related to physical activity domains and types within the context of climate change. While some physical activities may exacerbate climate change, others have the potential to mitigate its effects. In the realm of sports,³⁹ as exemplified by large-scale sporting events like the Olympic Games, it has been emphasized that sports can play a dual role: while many such events have made pledges and taken strides to reduce carbon footprint through improved logistics,³⁹ the high level of transportation and facility still yields high greenhouse gas emissions.²⁹ However, it is noted that despite strong rhetoric on sustainability, critiques highlight gaps between the Olympic movement's environmental discourse and its actual implementation efforts.⁴⁷ Conversely, within the domain of active transportation, modes such as walking and biking not only mitigate greenhouse gas emissions and, consequently, improve air quality^{31,42} but also play a significant role as a mitigating factor in postnatural disaster scenarios.²⁹ However, it is important to note that most research focuses on transport-shifting scenarios and their impacts on local air pollution, with limited empirical studies exploring the synergistic effects of integrating active transport with public transport development and the use of low-emission vehicles, all of which contribute to lower greenhouse gas emissions in urban settings.²⁹

These findings emphasize the necessity of a comprehensive approach involving policy reform, community engagement, and infrastructure development to fully harness the benefits of physical activity for climate mitigation. Further robust research is needed to inform targeted strategies for adopting active transport as an alternative to high-emission transportation modes. Additionally, research on recreational physical activity and climate change should investigate the carbon footprint associated with sports and leisure pursuits, aiming to develop guidelines for reducing CO₂ emissions from large-scale sports leagues, encompassing professional, university, and amateur sports. By evaluating the environmental impact of these activities and proposing methods to mitigate emissions, researchers can actively contribute to sustainability initiatives within the sports and active transportation sectors.

As climate change accelerates and physical inactivity remains a leading noncommunicable disease risk factor, unpacking the complex relationships between these major public health challenges is a priority. As observed in this comprehensive umbrella review, the predominant focus of recent studies on these topics is on specific domains of physical activity, such as sports or active transportation, and primarily focuses on mitigating greenhouse gas emissions. However, there is a conspicuous gap in the exploration of climate mitigation and adaptation mechanisms related to physical activity, and in the provision of evidence-based, practical recommendations for research, practice, and policy on these topics. More research is needed on the impact

of climate change on additional domains of physical activity, such as occupational activities, to understand the relationship more thoroughly between physical activity and climate change and to explore effective adaptation and mitigation strategies.

Future research should prioritize equity across geographical, cultural, and economic dimensions by investigating physical activity and climate change specifically in low- and middle-income countries, in which many of the world's most climate-vulnerable populations are located. While the richest nations have the highest carbon footprint,⁴⁸ the Global South most suffers from the severe consequences of climate change. The rapid increase in human production and consumption that began with colonialism⁴⁹ has degraded many environments and led to disproportionate health and climate risks for marginalized people at both global and local levels. Climate change and economic inequalities are pressing and interconnected challenges.⁵⁰ Prioritizing climate justice in health is crucial to addressing these issues effectively. Failure to do so can exacerbate inequalities within and between countries.⁵⁰ This urgency is demonstrated clearly by the absence of studies from low- and middle-income countries in our search, as well as the low percentage (18.5%) of studies included in these 7 reviews that were conducted in the Global South. Addressing the needs of refugees, particularly climate refugees, is paramount.

Future studies should also investigate the effectiveness of physical activity interventions, such as adapted sports,⁵¹ in promoting both the social integration and health of these individuals. Additionally, research should explore the impact of climate change on physical activity within traditional communities, especially indigenous and island communities whose lives and cultures are vulnerable to sea level rise. Understanding the effects of climate change on physical activity in these communities, within their distinct cultural and environmental contexts, can provide valuable insights for developing targeted interventions and policies to support resilience and adaptation efforts. Furthermore, incorporating mandatory climate change education into public health and sport sciences departments can better prepare future professionals to tackle climate change challenges effectively.⁵² Additionally, adopting a movement behavior²¹ approach for future interventions, with a focus on climate change, can enhance the development of comprehensive and effective strategies to mitigate the adverse effects of climate change on physical activity and health.²¹

This umbrella review has some limitations worth noting. First, we only included systematic reviews and meta-analyses published in English and in scientific literature. Second, the direction and type of climate change–physical activity relationships depicted in the studies frequently varied, leading to diverse conclusions. Third, umbrella reviews are inherently constrained by the quantity, quality, and comprehensiveness of available primary studies, though they offer benefits by summarizing existing evidence. Despite these limitations, this study underscores

important contributions. It evaluated the methodological quality of each included study, resulting in more consistent summaries of results. It also identified research gaps, identifying areas needing further investigation to better understand the relationship between physical activity and climate change. Moreover, it offered insights into potential strategies for mitigating climate change through adapting strategies aiming at promoting physical activity. By summarizing existing evidence and highlighting the dual benefits for health and environmental sustainability, this study provided valuable guidance for researchers, policymakers, and public health officials, aiding in the development of targeted interventions and policies.

Conclusion

This comprehensive umbrella review explored the intricate interplay between climate change and physical activity. Through the analysis of 7 thoroughly identified studies, it becomes evident that the relationship between these 2 factors is complex and multifaceted, with both positive and negative impacts observed depending on various contextual factors such as the domain or effect being measured, geography, and culture. The reviewed studies highlight the contrasting effects of climate change on physical activity, with rising temperatures potentially encouraging outdoor activities until a temperature threshold but air pollution and extreme temperatures discouraging such activities due to health concerns. Conversely, physical activity, particularly in the form of active transportation and improved logistics around large-scale sporting events, is shown to have the potential to mitigate climate change through the reduction of greenhouse gas emissions and alleviate postnatural disaster scenarios. However, certain aspects of physical activity, such as transportation linked to sporting events, may exacerbate the effects of climate change. This highlights the urgency of targeted research that delves into additional domains of physical activity, such as occupational activities, and practical strategies for adaptation and mitigation.

Moreover, this study unveils the crucial necessity for heightened engagement of the physical activity community in dialogues concerning climate action and global health. Discussions bridging these domains must give precedence to equity, attend to the requirements of marginalized populations, and account for the social, cultural, and economic factors influencing both physical activity and climate change. Formulating sustainable strategies and policies for physical activity, aimed at minimizing inadvertent environmental impacts, alongside enhancing climate resilience in physical activity infrastructure and planning, stands as imperative.

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Appendix 1: JBI Critical Appraisal Instrument for Systematic Reviews and Research Syntheses

JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses

Reviewer: _____ Date: _____
Author: _____ Year: _____ Record Number: _____

	Yes	No	Unclear	Not applicable
1. Is the review question clearly and explicitly stated?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Were the inclusion criteria appropriate for the review question?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Was the search strategy appropriate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Were the sources and resources used to search for studies adequate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Were the criteria for appraising studies appropriate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Was critical appraisal conducted by two or more reviewers independently?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Were there methods to minimize errors in data extraction?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Were the methods used to combine studies appropriate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Was the likelihood of publication bias assessed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Were recommendations for policy and/or practice supported by the reported data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Were the specific directives for new research appropriate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal: include Exclude Seek further info

Appendix 2: JBI Data Extraction Form for Review for Systematic Reviews and Research Syntheses

Study Details	
Author/year	
Objectives	
Participants (characteristics/ total number)	
Setting/context	
Description of interventions/ phenomena of interest	
Search Details	
Sources searched	
Range (years) of included studies	
Number of studies included /	
Types of studies included	
Country of origin of included studies	
Appraisal	
Appraisal instruments used	
Appraisal rating	
Analysis	
Method of analysis	
Outcome assessed	
Results/Findings	
Significance/direction	
Heterogeneity	
Comments	