Title: Cervical Cancer and Climate Change

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Abstract:

Background: The research question guiding this scoping review was*: "What does the literature reveal (since January 1, 2005) about the association between climate change—or its underlying environmental drivers—and cervical cancer?"* Methods: We conducted a comprehensive literature search using two major electronic databases: PubMed and Web of Science, for January 1, 2005, through July 30, 2024. 522 titles resulted from the search. One manuscript did not fit the research question after full review, leaving 10 articles. Results: Seven articles addressed ultraviolet (UV) radiation exposure. There were mixed results as to the exposure effect on cervical cancer rates. Two articles were more closely related to climate change – one discussed correlation between incidence and air pollution and the other discussed correlation between cervical cancer and average annual temperature. Conclusion: While direct evidence remains limited, findings suggest climate change may influence cervical cancer risk through pathways such as UV radiation, air pollution, and temperature changes. Policy Statement: Investing in resilient healthcare infrastructure and ensuring equitable access to preventive services are critical steps toward reducing the global burden of cervical cancer in the context of a changing climate.

1. Introduction

Recent research has highlighted a complex relationship between climate change and cervical cancer, with several interconnected factors contributing to both issues. Climate change, primarily driven by human activities[1-3] such as burning fossil fuels[4-6] and deforestation,[7-9] is not only affecting global temperatures and weather patterns[10-14] but also indirectly impacting human health, including cancer risk.[15-19] While direct evidence linking climate change to cervical cancer rates is limited,[20] the intersection of climate change and cervical cancer involves multiple pathways, including environmental exposures, socioeconomic factors, and disruptions to healthcare systems.[21] This scoping review focuses on literature examining the connection between changes in climate and the ensuing environmental exposures that may lead to cervical cancer.

Research indicates that climate change can alter environmental conditions that may influence cancer risk. This includes 1) Increased ultraviolet (UV) radiation. Climate change-induced ozone depletion leads to increased UV radiation exposure.[15 22-25] While UV radiation is primarily associated with skin cancers, it may have systemic effects on immune function, potentially impacting the body's ability to fight HPV infections, the primary cause of cervical cancer.[26-28] 2) Air pollution: climate change can worsen air quality by altering ventilation, dilution, and atmospheric chemistry.[29-32] Air pollution, particularly exposure to traffic-related hazardous air pollutants (HAPs), appears to play a significant role in increasing the risk of cervical cancer and its precursor lesions.[33-36] Specifically, benzene exposure has been linked to higher odds of cervical dysplasia, with a dose-response relationship observed. Diesel particulate matter (DPM) and polycyclic aromatic hydrocarbons (PAHs) were also associated with increased cervical dysplasia risk.[34] Long-term exposure to fine particulate matter (PM2.5) has also been associated with increased cancer mortality, including gynecological cancers.[37-42] A study using data from the NIH All of Us Research Program revealed a notable link between PM2.5 exposure and various cancers, including cervical cancers.[43] While human papillomavirus

(HPV) infection remains the primary cause of cervical cancer, air pollution appears to be an important modifiable risk factor that may contribute to the development and progression of cervical cancer.

1.1 Research Question and Review Design

The research question guiding this scoping review was*: "What does the literature reveal (since January 1, 2005) about the association between climate change—or its underlying environmental drivers—and cervical cancer?"* We employed a scoping review methodology to systematically map the existing literature on the connection between changes in climate and environmental exposures that may contribute to the development of cervical cancer. Scoping reviews are particularly useful for examining emerging evidence, identifying key concepts, and clarifying definitions within a broad research area. A general scoping review framework was used and enhanced by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines.

2. Search Strategy and Selection Criteria

2.1 Protocol and Registration

The protocol for this review was registered at Open Science Framework (osf.io/rhx39). Environmental factors included in the review are dust, UV radiation exposure (or a proxy of, such as vitamin D), and particulate matter. UV radiation, not usually considered a component of climate change, was also included because it can be affected by a variety of factors that do affect climate change – cloud cover,[44-47] greenhouse gases,[48-52] and dust.[53 54]

2.2 Eligibility Criteria

Full-text articles were then assessed for eligibility based on the following inclusion criteria:

1. **Population**: Studies involving human populations.
2. **Exposure**: Studies examining climate-related factors (e.g., temperature, humidity, extreme weather events) or environmental exposures linked to climate change.

3. **Outcome**: Studies reporting on cervical cancer incidence, prevalence, or related mechanisms.
4. **Study Design**: Peer-reviewed original research articles, reviews, and theoretical frameworks.

Studies were excluded if they did not address the connection between climate or environmental factors and cervical cancer, or if they were published before 2005.

2.3 Information Sources & Search Strategy

On July 30th, 2024 we conducted a comprehensive literature search using two major electronic databases: PubMed and Web of Science. The search strategy was designed to capture studies exploring the relationship between climate-related factors (e.g., weather, meteorology, climate change) and cervical cancer. The following search algorithms were used:

- **Web of Science**:
  (((ALL=(weather)) OR ALL=(meteorology)) OR ALL=(climate)) AND ALL=(cervical cancer)
- **PubMed**:
  (((climate[MeSH Terms]) OR (weather[MeSH Terms])) AND (cervical cancer[MeSH Terms]))

Filters were applied to include only titles published since January 1, 2005, because it was at this time researchers began to change their thinking about the connections between climate change and health.[55-57] Grey literature was excluded.

2.4 Data Processing

A total of 522 titles resulted from the search and after aggregation and de-duplication, 306 remained (Figure 1). Two independent reviewers (authors EC and TC) screened the titles and abstracts of the retrieved articles to identify studies relevant to the research question. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer.

Authors EC and TC reviewed the titles and selected those that could be associated in any way with the research question. At least one reviewer needed to select a title to keep it for the next round of reviews. After abstracts were pulled, EC and TC again reviewed and selected ones that indicated an association with the research question. At this stage, once again, at least one reviewer needed to select an abstract to keep it for the next round. For the final round (full text review), EC and TC reviewed 11 articles. One manuscript was deemed not to fit the research question after full review, leaving 10 articles for final analysis. EC and TC compiled notes on each article and compared the relevant methods and data items regarding climate variables and cervical cancer. Any disagreements were discussed. EC collated all into results with TC, AW, and NM evaluating for agreement.

3. Results

Seven of the ten articles included in the analysis addressed sunlight/UV radiation exposure. In terms of said exposure, there are mixed results as to the effect the exposure has on cervical cancer rates. Two found positive correlations between UV radiation exposure and cervical cancer rates. However, one took mid-point latitude measurement for the state (United States),[58] which could greatly influence the value of UV radiation used (example: California). The other was based on data from Iran and could be influenced by the changes in the ozone layer, as noted by the authors.[59] One study found that with increased UV radiation exposure by month over a 16-year study period, there was an increase in the average rate of dysplastic and carcinomatous cervical epithelial change in pap smears.[60] The remaining four found inverse relationships between UV radiation and cervical cancer incidence – lower UV radiation exposure correlated with higher cervical cancer incidence.[61-64]

One article linked the month of birth in Northern England to the incidence of cervical cancer in young women. Being born in fall/autumn months was linked to higher incidence of cervical cancer. The authors suspected that it was due to environmental factors around the time of birth. It should be noted that this analysis was on 85 cases in 15-24 years olds in 1968-2005.[65]

Two articles were more closely related to climate change than the other eight[66 67] – one discussed the correlation between cervical cancer incidence and different types of air pollution and the other discussed the correlation between cervical cancer and average annual temperature. The one linking cervical cancer incidence with air pollution did so through the use of HPV infections at daily outpatient visits in China. Overall, the authors worked to link short-term exposure to ambient air pollution (particulate matter – 10 micrometers or less, particulate matter – 2.5 micrometers or less, nitrogen dioxide, sulfur dioxide) to an increase in HPV infections (HPV infection-related cervical intraepithelial neoplasia). They found that ozone seemed to have a protective effect on HPV infections.[66] A different article found that cervical cancer had a positive correlation with higher average annual temperature , which was in the opposite direction of most of the other cancers studied in that article.[67]

4. Discussion

This scoping review aimed to explore the existing literature on the connection between climate change, environmental exposures, and cervical cancer. While direct evidence linking climate change to cervical cancer remains limited, this review identified several factors that may influence cervical cancer risk, whether through direct effects of climate change (e.g., air pollution) or secondary effects of climate change (e.g., effects from UV radiation). These pathways include differences UV radiation exposure,[58-65] air pollution,[66] and other environmental factors[67] that may interact with socioeconomic and healthcare system vulnerabilities to further increase the cervical cancer risk. The findings highlight the complexity of this relationship and underscore the need for further research to better understand the mechanisms and potential interventions.

4.1 Key Findings and Interpretation

The review revealed mixed findings regarding the role of UV radiation in cervical cancer risk. While some studies reported a positive correlation between UV radiation exposure and cervical cancer incidence,[58 59] others found an inverse relationship, suggesting that lower UV

radiation exposure was associated with higher cervical cancer rates.[61-64] These discrepancies may be attributed to methodological differences, such as variations in geographic location, measurement techniques, and confounding factors like vitamin D levels or ozone layer dynamics. For instance, the study by Khanjani in Iran noted that changes in the ozone layer could influence UV radiation effects,[59] while Hrushesky's study in Holland linked seasonal UV radiation variations to abnormal Pap smear results. [60]These findings suggest that UV radiation may have both protective and harmful effects on cervical cancer risk, potentially mediated by immune modulation or other mechanisms.

Air pollution emerged as a significant environmental exposure linked to cervical cancer. Studies such as Liang et al. demonstrated that short-term exposure to ambient air pollutants,[66] including particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide, and sulfur dioxide, was associated with increased HPV infections and cervical intraepithelial neoplasia. Notably, ozone appeared to have a protective effect, highlighting the complex interplay between different air pollutants and cervical cancer risk. These findings align with broader evidence linking air pollution to cancer mortality, including gynecological cancers, as seen in studies using data from the NIH All of Us Research Program.[43] The dose-response relationship observed for benzene exposure and cervical dysplasia further underscores the potential role of air pollution as a modifiable risk factor for cervical cancer.

The review also identified studies linking climate-related factors such as average annual temperature to cervical cancer incidence. Sharma et al. found a positive correlation between higher average annual temperatures and cervical cancer rates, contrasting with trends observed for other cancers.[67] This finding suggests that temperature may influence cervical cancer risk through mechanisms such as altered viral persistence, immune function, or behavioral changes. Additionally, the study by Basta et al. highlighted the potential impact of environmental factors around the time of birth on cervical cancer risk, with higher incidence observed among women

born in fall/autumn months in Northern England.[65] While this finding is intriguing, it warrants further investigation to elucidate the underlying mechanisms.

4.2 Implications for Public Health and Policy

The findings of this review have important implications for public health and policy. Climate change is a global challenge that exacerbates existing health disparities, particularly in low- and middle-income countries where cervical cancer burden is highest. The indirect pathways linking climate change to cervical cancer—such as air pollution, UV radiation, and temperature changes—highlight the need for integrated approaches to cancer prevention and climate adaptation. For example, policies aimed at reducing air pollution, such as stricter emissions standards and promotion of clean energy, could have dual benefits for both climate mitigation and cancer prevention. Similarly, public health campaigns to increase awareness of UV radiation risks and promote HPV vaccination could help mitigate the potential impacts of climate change on cervical cancer.

The review also underscores the importance of strengthening healthcare systems to address the dual challenges of climate change and cancer. Disruptions to healthcare services caused by extreme weather events or other climate-related factors could hinder cervical cancer screening and treatment efforts, particularly in vulnerable populations. Investing in resilient healthcare infrastructure and ensuring equitable access to preventive services are critical steps toward reducing the global burden of cervical cancer in the context of a changing climate.

4.3 Limitations

This scoping review has several limitations. First, the search was limited to two databases (PubMed and Web of Science) and studies published in English, which may have excluded relevant studies from other sources or languages. Second, the focus on peer-reviewed literature may have overlooked valuable insights from grey literature or non-traditional sources. Additionally, the heterogeneity of study designs, populations, and exposure measurements limited the ability to draw definitive conclusions about the relationship between climate change

and cervical cancer. Finally, the review primarily identified associative relationships rather than causal mechanisms, highlighting the need for more robust epidemiological and experimental studies.

4.4 Future Research Directions

This review identified several gaps in the literature that warrant further investigation. First, more research is needed to elucidate the mechanisms linking climate-related exposures, such as UV radiation and air pollution, to cervical cancer development and progression. Second, longitudinal studies are needed to assess the long-term impacts of climate change on cervical cancer risk, particularly in vulnerable populations. Third, studies examining the interaction between climate change, socioeconomic factors, and healthcare access could provide valuable insights into disparities in cervical cancer outcomes. Finally, interdisciplinary research integrating climate science, oncology, and public health is essential to develop effective strategies for mitigating the health impacts of climate change.

5. Conclusion

This scoping review highlights the complex and multifaceted relationship between climate change, environmental exposures, and cervical cancer. While direct evidence remains limited, the findings suggest that climate change may influence cervical cancer risk through pathways such as increased UV radiation, air pollution, and temperature changes. These findings underscore the need for integrated approaches to cancer prevention and climate adaptation, as well as further research to better understand the mechanisms and impacts of climate change on cervical cancer. Addressing these challenges will require collaboration across disciplines and sectors to ensure equitable and sustainable solutions for global health.

Statements and Declarations

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Data Availability: No datasets were generated in this review. Steps are provided in methods to recreate our selected manuscripts.

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Tables and Figures

Fig. 1. PRISMA Diagram