AMBIENT TEMPERATURE EXPOSURE AND RISK OF PRETERM BIRTH: A SCOPING REVIEW

by:

Navneet Mangat

BSN, British Columbia Institute of Technology, 2016

A SCHOLARLY PRACTICE ADVANCED RESEARCH (SPAR) PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Nursing)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

March 2022

The following individuals certify that they have read, and recommend to the Faculty of Graduate and Postdoctoral Studies for acceptance, the thesis entitled:

Ambient temperature exposure and risk of preterm birth: a scoping review

submitted by Navneet Mangat in partial fulfillment of the requirements for

the degree of Master of Science

in Nursing

Examining Committee:

Manon Ranger, Nursing, UBC
Supervisor

Maura MacPhee, Nursing, UBC
Supervisory Committee Member

Abstract

Background: Preterm birth (PTB) is the leading cause of global neonatal mortality, with rates steadily rising in Canada. Previous evidence suggests an association between prenatal ambient temperature exposure and PTB, however, this relationship remains poorly understood. As global climate change may exacerbate extreme temperature fluctuations, there is a need to clarify the relationship between temperature exposure and PTB risk. A scoping review was conducted to examine the current state of literature regarding prenatal ambient temperature exposure and PTB risk. **Methods**: A scoping review was conducted and 10 published articles were analyzed using the Arksey and O'Malley methodological framework and the Garrard Matrix Method. Systematic searches were conducted using CINAHL, MEDLINE, and Web of Science databases. **Findings**: Significant associations were reported between high ambient temperature exposure and PTB risk during all three trimesters, with the second trimester as the most commonly identified period of vulnerability. The relationship between low ambient temperature exposure and PTB risk remained inconclusive, with negative and positive associations observed during different gestational trimesters. **Conclusion**: The review of the literature suggested that prenatal ambient temperature exposure is a significant risk factor for PTB. Based on the findings, nursing-led initiatives are recommended to develop appropriate client education, risk mitigation policies, and climate-based nursing curriculum. Future research is recommended to address gaps within the literature, specifically the consideration of demographic factors, rural populations, and colder/ dry climate regions to further clarify the relationship between ambient temperature exposure and PTB risk.

Lay Summary

Preterm birth is the leading cause of newborn death around the world, with rates steadily increasing in Canada. Previous research has shown that exposure to extreme heat is related to preterm birth. Global temperature changes due to climate change heighten concerns about extreme temperature effects on maternal health. The goal of this study was to explore the relationship between exposure to high and low temperature during pregnancy and risk of preterm birth. The findings from this study suggest that heat exposure during pregnancy is related to higher risk of preterm birth, especially when exposed during the second trimester. Based on the findings of this study, it is recommended for nurses to provide prenatal education about avoiding heat exposure during pregnancy, and to include content about the maternal health effects of climate change into nursing education programs. Future research is needed to explore the effects of temperature exposure on pregnant women living in colder climates and lower resource settings.

Preface

This project is an original, unpublished, independent work by the author. Ethics approval was not required for this study. Dr. Manon Ranger and Dr. Maura MacPhee assisted with manuscript revisions and read and approved the final manuscript.

Table of Contents

List of Tables

List of Figures

Acknowledgements

This project could not have been completed without the insight, expertise, and support of various individuals. My sincerest gratitude to my supervisor Dr. Manon Ranger, for your unwavering patience, guidance, and dedication throughout this process. To my committee member, Dr. Maura MacPhee, thank you for your enthusiasm, expertise, and invaluable feedback. A special thank you to Katherine Miller and Ursula Ellis from the UBC library team for your insightful guidance.

To my family and friends, thank you for your unconditional support and encouragement, and especially to Tan, for the countless café days over the last two years.

Dedication

For my mother and father, who taught me to never stop learning.

Chapter 1: Introduction

1.1 Background

Preterm birth (PTB), or prematurity, is defined as delivery before 37 weeks of gestation, and is considered a major global health concern due to its associated morbidity and mortality (Harrison & Goldenberg, 2016; Vogel et al., 2018). Prematurity is the leading cause of neonatal mortality, affecting about 11% of deliveries worldwide (Harrison & Goldenberg, 2016; Vogel et al., 2018). Acute neonatal morbidities associated with PTB include sudden infant death syndrome (SIDS), respiratory distress syndrome (RDS), sepsis, neonatal hypoglycemia, necrotizing enterocolitis (NEC), feeding difficulties, visual and hearing impairments, and various neurological conditions such as cerebral palsy and hypoxic ischemic encephalopathy (Johnston et al., 2014; Vogel et al., 2018). Long-term childhood morbidities of PTB include neurodevelopmental impairments and behavioral, socio-emotional, and learning difficulties (El-Mazahi et al., 2014; Johnston et al., 2014; Synnes et al., 2010; Synnes et al., 2017; Vogel al., 2018). Maternal implications of preterm labour (PTL) and PTB include increased obstetrical interventions, caesarean delivery, and postpartum depression (Harrison & Goldenberg, 2016; Vogel et al., 2018).

Prematurity also imposes significant economic burdens upon the Canadian health care system due to increased health care resource utilization, higher hospital admission rates, longer length of hospitalization, and increased workload demands upon the health care system (Johnston et al., 2014; Rios et al., 2021). The median inpatient cost of admission to a Canadian tertiary neonatal intensive care unit for preterm neonates exceeded $20,000 due to the combination of nursing labour, respiratory support, medication and procedural costs (Rios et al., 2021). The rates of PTB have steadily increased in many higher income countries and have risen from 6.4% to 8.2% from 1981 to 2017 within Canada (Joseph et al., 2007; Public Health Agency of Canada, 2017; Vogel et al., 2018).

Climate change and extreme temperature fluctuations over the last decade have been linked to various negative health outcomes among vulnerable populations, including pregnant women (Giudice et al., 2021; Peters et al., 2020). Increased risks of cardiovascular disease, asthma, vector-borne illness, low birthweight, preterm birth and stillbirth have been linked to climate change hazards such as ambient air pollution and heat exposure (George et al., 2017; Giudice et al., 2021; Peters et al., 2020). As the global climate change crisis may further exacerbate extreme temperature fluctuations, there is a critical need to clarify the relationship between prenatal ambient temperature exposure and PTB in order to inform public intervention strategies, decision making, and education (Giudice et al., 2021; Sorensen et al., 2018; Zhang et al., 2017).

Complex biomedical, socioeconomic, and environmental factors have been associated with spontaneous preterm birth, yet the underlying etiology of PTB remains poorly understood (British Columbia Reproductive Care Program, 2005; Frey & Klebanoff, 2016; Muglia & Katz, 2010; Vogel et al., 2018). Zhang et al.'s (2017) findings suggested an association between ambient prenatal temperature and PTB and the authors called for further research to explore the relationship between ambient temperature and preterm birth, particularly in identifying gestational time periods of vulnerability (exposure windows) to the effects of ambient temperature exposure. Investigating the relationship between prenatal ambient temperature exposure and PTB is critical to better understanding the complex etiology of PTB and predicting its incidence, and may have significant implications for reducing maternal-child burden (Zhang et al., 2017).

1.2 Personal Significance of Issue

Within my role as a perinatal nurse at Surrey Memorial Hospital's Family Birthing Unit, I have observed increasing cases of PTB in the last five years, and especially so during heat waves and periods of rapid temperature fluctuations. According to the Public Health Agency of Canada (2017) and Perinatal Services British Columbia's (2005) surveillance reports, the rates of PTB have increased in Canada and British Columbia in recent years.

I have cared for maternal patients presenting with preterm labour (PTL) throughout the perinatal continuum, and have witnessed the significant challenges associated with caring for premature newborns in the postpartum period. I often counsel my maternal patients on modifiable risk factors for PTL and PTB, however, recent temperature extremes due to climate change prompted my inquiry into the impacts of temperature exposure on risk of preterm labour and birth, and gestational periods of vulnerability. These unanswered questions incited me to further examine the impact of ambient temperature exposure on risk of preterm birth, in order to inform my practice in educating women on potential risk factors for preterm birth and relevant mitigating strategies. My aim is to conduct a scoping review in order to examine the recently published literature, summarize the current state of evidence, recommend future areas of research, promote awareness, and inform prevention strategies.

1.3 Purpose of Project and Significance for Nursing Practice

While additional studies have been conducted in recent years, not since 2016 has there been a comprehensive review summarizing the most recent body of evidence surrounding the topic of ambient temperature exposure and PTB. Reviewing the current literature base is essential in order to identify knowledge gaps and guide future research recommendations. The purpose of this Scholarly Practice Advancement Research (SPAR) project is to conduct a scoping review of the literature to examine the association between prenatal ambient temperature exposure and the risk of PTB among healthy pregnant women, and to identify gestational periods of vulnerability to the effects of ambient temperature exposure. The overall aim of this proposed scoping review is to identify knowledge gaps and guide future recommendations for research and clinical practice, and to disseminate the findings of this project to perinatal care providers, educators, and stakeholders in order to enhance awareness and discourse surrounding the impacts of climate change on perinatal outcomes.

As this project is a scoping review, summarizing and disseminating the findings may promote awareness among perinatal nurses and educators regarding the impacts of temperature exposure on PTB (Arksey & O'Malley, 2005). The nursing profession is well posited to advocate for policies to mitigate climate change, and thus nurses may utilize the findings of this scoping review to champion health promotion initiatives to address the perinatal health impacts of climate change and extreme temperature exposure (Kalogirou et al., 2020; Nicholas & Breakey, 2017). By reviewing and summarizing the current state of evidence, this scoping review may support public health nurses and antepartum nurses in providing adequate counselling and education to pregnant women, in order to mitigate the risk of PTB in relation to temperature variations. Additional insights gleaned from this scoping review may potentially support the development of environmental health nursing curriculum in nursing education programs, which has been mandated as a priority area for nursing curriculum by the Canadian Nurses Association, the Canadian Association of Nurses for the Environment and various nursing leaders (Canadian Nurses Association, 2017; Kalogirou et al., 2020; Leffers et al., 2017). Furthermore, this scoping review may guide recommendations for future areas of research by identifying conflicting evidence and potential gaps in the literature.

1.4 Research Questions

The main and secondary research questions developed for the purpose of this review are:

1. Does exposure to extreme ambient temperature in the prenatal period affect risk of preterm birth?
2. At what gestational time period (exposure window) are pregnant women most vulnerable to the effects of extreme ambient temperature exposure on their risk of preterm birth?

Extreme temperature is defined as temperature significantly above or below expected mean local temperature.

1.5 Chapter Summary

PTB is the leading cause of neonatal mortality and is associated with various acute neonatal and long-term childhood morbidities (El-Mazahi et al., 2014; Harrison & Goldenberg, 2016; Synnes et al., 2010; Synnes et al., 2017; Vogel et al., 2018). PTB also places significant economic burdens upon the Canadian and provincial health care systems due to health care resource utilization and workload demands (Jonhston et al., 2014; Rios et al., 2021). Given the current global climate change crisis, investigating the relationship between prenatal ambient temperature exposure and PTB is critical to understanding the complex etiology of PTB and may have significant implications for reducing maternal-child burden (Zhang et al., 2017).

Chapter 2: Methodology

This chapter describes the methodology utilized to conduct the systematic literature search and selection. I will explain the rationale for procedures used, main concepts of my main research question, as well as the search process. Figures are included in this chapter in order to illustrate search strategies and the article selection method.

2.1 Scoping Review Methodology

This SPAR project was completed by conducting a scoping review of the current literature, exploring the relationship between extreme ambient temperature exposure and risk of preterm delivery, to identify gestational time period of vulnerability. A scoping review aims to analyze the range of evidence base surrounding a topic (Arksey & O'Malley, 2005; Hanneke et al., 2017; Polit & Beck, 2020). Scoping reviews focus on mapping information about complex topics in order to inform future areas of investigation (Arksey & O'Malley, 2005; Munn et al., 2018). Scoping reviews highlight significant research gaps and offer an intellectual overview of what is currently known about a topic (Munn et al., 2018). While scoping reviews entail conducting a systematic search and critical review of the literature, they omit certain elements of the systematic reviews (such as meta-analyses) in order to ensure timely responses for guiding stakeholders regarding urgent issues (Arksey & O'Malley, 2005; Munn et al., 2018). Given the complex interplay of environmental, biological, and socioeconomic factors within this SPAR topic, and the urgency of the climate crisis, a scoping review was conducted in order to map current evidence and identify research gaps regarding the impacts of ambient temperature variation on risk of PTB.

This scoping review followed the Arksey and O'Malley Framework (Arksey & O'Malley, 2005). This methodological framework consists of five stages: identifying the research question, identifying relevant studies, study selection, charting data, collating, summarizing, and reporting results, and optional consultation (Arksey & O'Malley, 2005). This scoping review also followed the Preferred Reporting Items for Systematic Review and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) checklist, as discussed by Tricco et al. (2018). This checklist was developed by an expert panel following published guidance from the Enhancing the Quality and Transparency of Health Research (EQUATOR) Network and is based upon the Arksey & O'Malley Framework (Tricco et al., 2018). The Garrard Matrix Method (Garrard, 2017) was also utilized in order to organize and synthesize data extracted from each article, in order to promote a structured and rigorous review of the current literature.

2.2 Systematic Search Process

2.2.1 Main Concepts of Research Question

In the context of this SPAR project, the population of "pregnant women" considered cis-gender women from conception to delivery. The concept of "preterm birth" was defined as delivery before 37 completed weeks of gestation. The concept of "ambient temperature exposure" was defined as outside air temperature in the geographical region of maternal residence. The main concepts are presented in Table 1.

Table 1

Main Concepts of Research Question

Population	Pregnant women
Concept 1	Preterm birth
Concept 2	Ambient temperature exposure

2.2.2 Information Sources

In order to find relevant articles addressing my main research question, I searched several databases. I consulted with the University of British Columbia nursing librarian team throughout the research process. In order to maximize relevant articles and minimize redundancy, keyword searches were conducted using the Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE(Ovid), and Web of Science databases. Searches on all databases were conducted between September and October 2021.

2.2.3 Search Strategies

The same search terms were used in both the CINAHL, MEDLINE, and Web of Science databases, utilizing MeSH headings (MH) and keywords, to be found in the titles (TI/ti), abstracts (AB/ab), or bodies of relevant articles. Search terms included: “temperature exposure”, “ambient temperature”, “heat wave”. Truncated and inclusive search terms “prematur*”, “pregnan*”, “antenatal”, “maternal”, “perinatal”, “birth*”, and “deliver*” were used in order to cover aspects of the main research question. Boolean operators (ie. AND, OR, and NOT) were utilized in order to combine keywords and MeSH headings. Tables 2 to 4 specify the combination of search terms and the number of relevant articles each search strategy yielded in the three databases.

Table 2

CINAHL Search

Search #	Search term(s)	# articles found	# relevant articles
12	Limiters: 2016, English	34	4
11	S7 AND S10	74	
10	S8 OR S9	20,402	
9	"temperature exposure" OR "ambient temperature" OR "heat wave"	1,174	
8	(MH “Temperature+”)	19,868	
7	S3 AND S6	25,205	
6	S4 OR S5	36,313	
5	("prematur*" OR "preterm") AND ("birth*" OR "deliver*")	34,010	
4	(MH “Childbirth, Premature”)	11,568	
3	S1 OR S2	333,159	
2	"pregnan*” OR "prenatal" OR "antenatal" OR "perinatal" OR "maternal"	327,807	
1	(MH "Pregnancy+")	228, 554	

Table 3

MEDLINE (Ovid) Search

Search #	Search term(s)	# articles found	# relevant articles
14	Limiters: English and 2016 publication	81	8
13	9 AND 12	169	
12	10 OR 11	444,366	
11	("temperature exposure" or "ambient temperature" or "heat wave").mp	20,066	
10	exp Temperature/	432,331	
9	6 AND 8	62,261	
8	4 OR 7	96,476	
7	5 AND 6	96,476	
6	("birth*" or "deliver*").mp	1,182,673	
5	("prematur*" or "preterm").mp.	250,578	
4	exp Premature Birth/	16,280	
3	1 OR 2	1,227,280	
2	("pregnan*" or "prenatal" or "antenatal" or "perinatal" or "maternal").mp	1,214,129	
1	exp Pregnancy/	934,485	

Table 4

Web of Science Search

Search #	Search term(s)	# articles found	# relevant articles
3	3 and 2021 or 2020 or 2019 or 2018 or 2017 or 2016 (Publication years)	150	10
2	1 AND Pregnancy or Humans or Temperature or Premature birth or Maternal Exposure (MeSH Headings)	466	
1	(((TS=("pregnan*" OR "prenatal" OR "antenatal" OR "perinatal" OR "maternal"))) AND TS=(("preterm" OR "prematur*") AND ("birth*" OR "deliver*"))) AND TS=("temperature" OR "temperature exposure" OR "ambient temperature" OR "heatwave")	509	

2.3 Literature Selection Process

2.3.1 Inclusion and Exclusion Criteria

Articles were included in this scoping review if they were published from 2016 and onwards, in order to capture the most recent body of evidence. Further inclusion criteria were articles that included ambient temperature variation as a predictor variable, and PTB as an outcome variable. Articles were included if they were quantitative studies, including systematic review and meta-analyzes. Articles which were duplicates, included non-human subjects, not available in English, and not available in full-text were excluded. To answer the secondary question, further exclusion criteria included studies that did not measure and report gestational weeks at delivery and studies that did not investigate windows of exposure throughout the pregnancy.

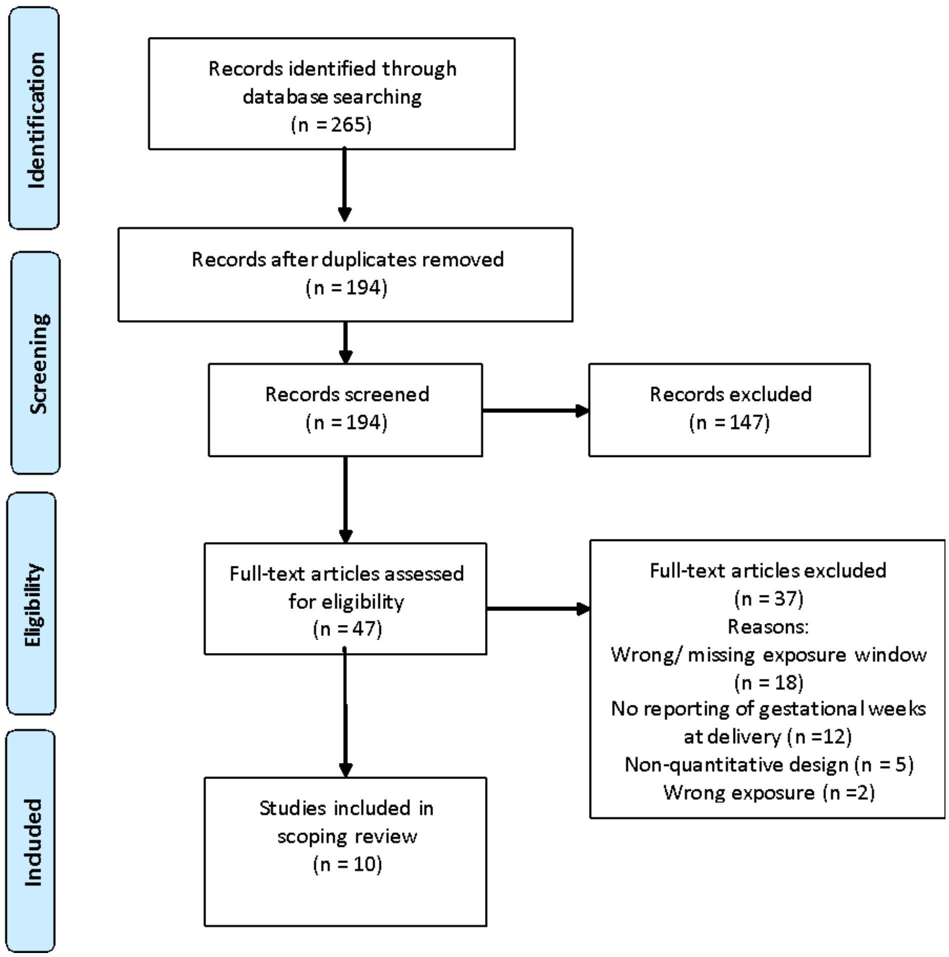
2.3.2 Study Selection, Categorization, and Data Extraction

The process recommended by the Joanna Briggs Institute (JBI) was applied when selecting studies to include within this scoping review (Peters et al., 2020). Combinations of search terms in the form of keywords and MeSH headings were applied in order to identify relevant literature, as seen in Tables 2-4. Relevant articles were then screened based upon their title and abstracts; articles were excluded if they did not meet inclusion criteria and if they were duplicates from other searches (Peters et al., 2020). The remaining articles were independently read and reviewed in their full-text, and the final literature included in this scoping review was determined by which articles met inclusion and exclusion criteria as described in Section 2.3.1. A flow chart of the review process was generated, outlining the number of relevant papers from each database, screening and elimination of duplicates, and the final 10 articles which met eligibility criteria and were included in this review (see Figure 1). The flow chart was created based on the PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies (Tricco et al., 2018).

Selected articles were categorized using a tabular format, as per the Garrard Matrix Method (2017). Relevant data was extracted and analyzed in order to answer the research questions guiding this scoping review. A table was created including the following information: author(s), year of publication, country of origin, study/ article design, details of the relationship between ambient temperature exposure and PTB risk, and gestational time periods of vulnerability to ambient temperature exposure (see Table 5, found in Chapter 3).

Figure 1

Flow Chart of Article Selection



2.4 Chapter Summary

In this chapter, I have described the methodology used to conduct the literature search and article selection for this scoping review. Various strategies and the main concepts being searched were described. The literature selection process was specified, including tables to outline the search strategies and a figure to display the flow of article elimination and selection, resulting in the final 10 articles retained and reviewed for this scoping review. The following chapter provides a comprehensive review of the data extracted from these selected articles, as they pertain to the purpose of this SPAR project.

Chapter 3: Findings

In this chapter, I describe and discuss the results in regard to the 10 articles included in this scoping review. The data collected and deemed relevant to the purpose of this SPAR project have been outlined in a table and are also comprehensively examined throughout the chapter.

3.1 Table of Analysis of Findings Included in Scoping Review

The following tables incorporated the Garrard Matrix Method (2017) recommendations for data organization and extraction. Table 5 is organized by article number, author(s) and year of publication, country of origin, study/article design (including number of participants), population demographics, operational definitions of temperature exposure, details of the relationship between ambient temperature exposure and PTB risk, and gestational time periods of susceptibility to ambient temperature exposure. Operational definitions of temperature are reported in degrees Celsius (°C). Associations between PTB and ambient temperature exposure are reported in Hazard Ratios (HR), Odds Ratios (OR), and 95% confidence intervals (CI). Tropical climates are defined as regions where the lowest monthly temperature is ≥ 18 °C (Chen & Chen, 2013). Humid subtropical climates are defined as regions in which the coldest month temperature is between -3°C and 18°C, and in which the warmest month temperature is ≥ 22 °C (Chen & Chen, 2013). Tables 6 -7 include a summary of the associations reported in each article, with identified gestational periods of vulnerability.

Table 5

Analysis of Findings Included in Scoping Review

Authors	Country of Origin (Climate Zones)	Design (n)	Demographics	Operational Definitions of Temperature Exposure and Outcome Assessment
He et al., 2016	China: -Humid -Subtropical -Urban	Retrospective case control N=838,146	Population: - Singleton - Vaginal births - Average maternal age 26.3 years	Operational definitions of temperature exposure: -Weekly average temperature measurements for each gestational week -Daily temperature data collected by meteorological station -Temperature definitions based on percentile of local temperature distribution (01/2001-12/2011) Outcome Assessments: -Median temperature: 24.4 °C -Extreme cold, moderate cold, moderate heat, and extreme heat over 11-year period: 7.6, 11.2, 31.9, 30.7 °C
Key Findings ● Moderate cold (*HR* = 1.129, *95% CI* 1.07, 1.19, $p < 0.05$), moderate heat (*HR* = 1.08, *95% CI* 1.02, 1.13, $p < 0.05$), extreme cold (*HR* = 1.18, *95% CI* 1.10, 1.26, $p < 0.05$) and extreme heat exposure (*HR* = 1.11, *95% CI* 1.03, 1.18, $p < 0.05$) were positively associated with PTB risk, with the strongest association occurring during the four weeks before delivery. ● Extreme cold temperature was significantly associated with risk of PTB during the following exposure windows: one week before delivery (*HR* = 1.14, *95% CI* 1.09, 1.20, $p < 0.05$), four weeks before delivery (*HR* = 1.18, *95% CI* 1.10- 1.26, $p < 0.05$), late pregnancy (*HR* = 1.12, *95% CI* 1.05, 1.21, $p < 0.05$), and cumulative pregnancy exposure (*HR* = 1.12, *95% CI* 1.0, 1.21, $p < 0.05$). ● Extreme heat was significantly associated with PTB risk during the following exposure windows: four weeks before delivery (*HR* = 1.10, *95% CI* 1.03, 1.18, $p < 0.05$), late pregnancy exposure (*HR* = 1.10, *95% CI* 1.03 - 1.18, $p < 0.05$), and cumulative pregnancy exposure (*HR* =1.10, *95% CI* 1.02, 1.18, $p < 0.05$) ● A stronger association between extreme heat and PTB was observed during 20-31 weeks (*HR* = 1.45, *95% CI* 1.15, 1.83, $p < 0.05$) and 32-34 weeks (*HR* =1.29, *95% CI* 1.08, 1.54, $p < 0.05$) gestation.				

<table>
<tr><td>Guo et al., 2018</td><td>China:
-Humid
-Tropical, subtropical
-Rural</td><td>Retrospective case control
N=1,020,0471</td><td>Population:
-Singleton
-Live vaginal births
-Maternal age 15-49 years; 83% were 20-29 years
-93.6% urban, 6.4% rural inhabitants</td><td>Operational Definitions:
-Temperature defined as cold, moderate, and hot based on percentiles of average temperature distribution (01/2010-12/2013)
-Study regions categorized as cold (<5th percentile), medium (5-95th percentile), and hot (>95th percentile) areas based on local average temperature by cluster analysis</td></tr>
<tr><td colspan="5">Key Findings
In hot regions, hot temperature exposure during the four months before pregnancy was associated with a 22.9% greater PTB risk (95% CI: 16.6%, 29.5%, $p < 0.05$). Hot temperature exposure throughout the pregnancy was also associated with an increased risk of PTB at gestational weeks 24, 26 to 28, 33, and 35 to 36.
In hot regions, hot temperature exposure was associated with increased PTB risk compared to moderate temperature exposure, during the following exposure periods: gestational weeks 1-7 (OR 1.11, 95 % CI 1.05, 1.17, $p < .001$), weeks 8-14 (OR = 1.15, 95% CI 1.09, 1.21, $p < .001$), weeks 15-21 (OR = 1.12, 95 % CI 1.05, 1.17, $p <.001$), and one week before delivery (OR = 1.12, 95% CI 1.01, 1.13, $p = .022$).
In hot regions, cold exposure was associated with lower PTB risk compared to moderate temperature exposure during the following exposure periods: gestational week 1-7 (OR = .85, 95% CI .80, .91, $p < .001$), weeks 8-14 (OR = .79, 95% CI: .74, .84, $p < .001$), weeks 15-21 (OR = .81, 95% CI .84, .95, $p < .001$), and four weeks before delivery (OR = .87, 95% CI .82, .92, $p < .001$). Specifically, cold exposure during gestational week 8-14 was associated with a 21.2% (95% CI: 16.2, 25.9%) lower risk of PTB.
In medium regions, hot temperature exposure during the four weeks before delivery was associated with increased PTB risk (OR = 1.16, 95 % CI: 1.09, 1.22, $p < .001$). In medium temperature regions, cold exposure during gestational weeks 8-14 and 15-21 was associated with a 14.4% (OR = .86, 95% CI: .81, .91, $p < 0.001$) and 7.7% (OR = .92, 95% CI: .874, .98, $p = .004$) reduced risk of PTB, respectively.
In cold regions, exposure to cold temperature during gestational weeks 15-21 was associated with a lower PTB risk (OR = .90, 95% CI .82, .98, $p = .017$) compared to exposure to moderate temperatures.
</td></tr>
<tr><td>Li et al., 2018</td><td>Australia
-Humid
-Subtropical
-Urban</td><td>Retrospective case control
N=289,351</td><td>Population:
-Single and multiple births
-Maternal age: 77.9% were < 35 years
-Live births</td><td>Operational Definitions:
- Daily temperature data collected from meteorological station
- Reference temperature was defined as the ambient temperature with minimum-prevalence of PTB
- Temperature definitions based on percentile of local temperature distribution (1994-2013)

Outcome Assessments:
- Temperatures: 14.6 °C for 1st trimester (1-12 weeks), 18.6 °C for 2nd trimester (13-28 weeks), and 19.5 °C for 3rd trimester (≥29 weeks)
- Daily mean, minimum, median, maximum temperature over 19 years period: 20.7, 7.4, 21.0, 31.5°C</td></tr>
</table>

				-Daily mean temperature low, moderate low, moderate high, high: 5^{th}, 25^{th} (17.5°), 75^{th} (23.9°C), 95^{th} percentile

Key Findings

- Significant association between mean ambient temperature exposure during the 3^{rd} trimester and risk of PTB showed a U-shaped curve.
- Exposure to low (5th percentile) temperature during the 3^{rd} trimester of pregnancy (> 29^{th} gestational week) was significantly associated with increased risk of PTB (*HR* = 1.21, *95% CI* 1.16, 1.27, $p < .05$).
- Exposure to high (95th percentile) mean temperature during the third trimester of pregnancy was significantly associated with increased risk of PTB (*HR* = 1.21, *95% CI* 1.16, 1.26, $p < .05$).
- The magnitude of the effects of mean daily temperature on the risk of PTB changed from 1994 to 2013. The association between third trimester low temperature exposure and PTB increased from 1994 (*HR* = 1.20, *95% CI* 1.14, 1.25, $p < .05$) to 2013 (*HR* = 1.56, *95% CI* 1.46, 1.66, $p < .05$). In contrast, the association between third trimester high temperature exposure and PTB decreased from 1994 (*HR* = 1.53, *95% CI* 1.44, 1.63, $p < .05$) to 2013 (*HR* = 1.19, *95% CI* 1.13, 1.25, $p < 0.05$).

Zheng et al., 2018	China -Humid -Subtropical -Urban	Retrospective case control N=3,604	Population: -Live births -Maternal age: 70% < 30 years old	Operational Definitions: -Temperature data collected from meteorological station (2004-2010) -Case exposures to outdoor ambient temperature during the conception month, 1^{st} trimester, 2^{nd} trimester, 3^{rd} trimester, birth month, and entire pregnancy calculated based on monthly mean temperature. -Trimesters undefined -Extreme heat day: daily temperature > 90^{th} percentile of temperature distribution -Extreme cold day: daily temperature < 10^{th} percentile of temperature distribution -Low temperature (<50^{th} percentile) and high temperature (> 50^{th} percentile) during each gestational period. Outcome Assessments: -Mean reference temperature: 11-17 °C. -Total 35.5 extreme heat days (>30°C) -Total 31.7 extreme cold days (<6°C) -Median temperature for conception month, 1^{st} month, 1^{st} trimester, 2^{nd} trimester, 3^{rd} trimester, birth month, entire pregnancy: 19.8, 18.0, 18.9, 19.5, 19.9, and 18.2 °C

Key Findings

- Increased PTB risk was significantly associated with low ambient temperature exposure during the following exposure periods: conception month (OR = 1.06, *95% CI*: 1.02, 1.12, $p \leq$ 0.01), 3rd trimester (*OR* = 1.09, *95% CI*: 1.03, 1.16, $p \leq 0.01$), and entire pregnancy (*OR* = 2.39, *95% CI*: 1.93, 2.95, $p \leq$ 0.001).
- Increased PTB risk was significantly associated with high ambient temperature exposure during the following exposure periods: conception month (High *OR* = 1.14, *95% CI* 1.04, 1.24, $p \leq 0.01$), 1st trimester (*OR* = 1.24, *95% CI*: 1.12, 1.35, $p \leq 0.001$), 3rd trimester (*OR* = 1.22, *95% CI*: 1.10, 1.35, $p \leq$ 0.001), and entire pregnancy (*OR* = 2.57, *95% CI*: 1.98, 3.33, $p \leq 0.001$).
- High ambient temperature exposure during 2nd trimester was significantly associated with lower PTB risk (*OR* = 0.86, *95% CI*: 0.80, 0.93, $p \leq 0.001$). There was no significant association between low ambient temperature exposure during the 2nd trimester and PTB risk.
- Increased PTB risk was associated with exposure to extreme cold days (*OR* = 1.42, *95% CI*: 1.01 - 2.00, $p \leq 0.05$) and extreme heat days (*OR* = 1.51, *95% CI*: 1.05 - 2.18; $p \leq 0.05$) in the entire pregnancy by a two-day increase of extreme heat or cold days.
- Exposure to extreme heat days during the 3rd trimester was significantly associated with increased PTB risk (*OR* = 1.14, *95% CI*: 1.04, 1.25; $p \leq 0.01$). Exposure to extreme cold days during the 3rd trimester was significantly associated with increased PTB risk (*OR* = 1.09, *95% CI*: 1.01, 1.18, $p \leq 0.05$) .
- Exposure to extreme cold days during the 2nd trimester was significantly associated with higher PTB risk (*OR* = 1.37, *95% CI*: 1.15, 1.62, $p \leq 0.001$), whereas exposure to extreme heat days was significantly associated with lower PTB risk (*OR* = 0.59, *95% CI*: 0.49, 0.70, $p \leq .001$).

Zhong et al., 2018	China -Humid -Subtropical -Urban	Retrospective case control N=3,509	Population: -Live births 2006-2007	Operational Definitions: -Temperature definitions based on percentiles of average temperature distribution (2006-2007) -Temperature data collected from meteorological station -The amount of time each case was exposed to the ambient temperature during 24h/day, daytime, night time, an extreme heat day in a whole year, and different seasons during different trimesters and entire pregnancy were respectively assessed in accordance with average temperature of 24h/day. -Seasons: (March-May), Summer (June-August), Autumn (September-November), and Winter (December-February). -Daytime temperature exposure: 08:00 - 19:00 -Nighttime temperature exposure: 20:00 - 07:00 -Extreme heat day: >90th percentile (30°C) -Temperature increase: 1°C increase in temperature -Trimesters: 1st (1-12 wks), 2nd (12-24 wks), 3rd (>28 wks) Outcome Assessments: -Mean temperature: 18.5°C -Max temperature: 28.°C -Min temperature: 6.8° -Number of extreme heat days: 35.6

Key Findings • OR (*95% CI*) was estimated for one day increase in extreme heat day (daily temperature ≥ 30 °C) during each time window. There was a significant positive association between PTB and exposure to extreme heat days during 2nd trimester (*OR* = 1.01, *95% CI* = 1.00, 1.02, $p < 0.05$). There was a significant negative association between PTB and exposure to extreme heat days during 3rd trimester (*OR* = 0.99, *95% CI* = 0.96, 0.99, $p < 0.01$). • ORs were estimated for 1°C increase in temperature during each time window. PTB was significantly related to the total temperature throughout entire pregnancy, with an OR (*95% CI*) = 1.31 (1.11, 1.62, $p < 0.05$) for increase of 1°C in temperature exposure. Exposure to temperature increase during 2nd trimester (*OR* = 1.51, *95% CI* = 1.31. 1.74, $p < 0.001$) and 3rd trimester (*OR* = 1.44, *95% CI* = 1.17, 1.76, $p < 0.001$) during the spring were positively associated with PTB. • During summer, exposure to temperature increase was positively associated with PTB in 1st trimester (*OR* = 1.93, *95% CI* = 1.32, 2.82, $p < 0.001$) and 2nd trimester (*OR* = 1.77, *95% CI* = 1.32, 2.37, $p < 0.001$) time windows.				
Wang et al., 2019	Australia -Humid -Subtropical -Urban/rural	Retrospective case control N=277,133	Population: -Singleton births (2000-2010)	Operational Definitions: -Daily maximum temperature recorded by the meteorological stations (1999-2010) -Heat wave definitions (HWD) from November-March: HWD2, and HWD 3 were respectively defined as daily maximum temperature >90th percentile lasting 2, 3, or 4 days. -HWD4, HWD5, and HWD6 were respectively defined as daily maximum temperature >95th percentile lasting 2, 3, or 4 days. Outcome Assessments: -Daily max temperatures: 20.4 - 40.2 °C in warm months (November-March), and 13.58 - 36.67 °C in other seasons (December-February). -Median value of max temperatures was 29.08 °C during warm months, and 22.05 °C in other months.
Key Findings • Heat wave exposure was significantly associated with PTB risk during all gestational months of exposure for all six heat wave definitions. The strongest associations were found during 2nd gestational month for HWD1 (*HR* = 1.42, *95% CI* = 1.29, 1.56, $p < 0.05$) and HWD2 (*HR* = 1.44, *95% CI* = 1.31, 1.59, $p < 0.05$) and HWD6 (*HR* = 1.29, *95% CI* = 1.15 - 1.42, $p < 0.05$), 4th gestational month for HWD3 (*HR* = 1.53, *95% CI* = 1.39, 1.68, $p < 0.05$) and HWD4 (*HR* = 1.31, *95% CI* = 1.20, 1.42, $p < 0.05$), and 6th gestational month for HWD6 (*HR* = 1.50, *95% CI* = 1.35, 1.63, $p < 0.05$).				

Liu et al., 2020	China -Humid -Subtropical -Urban	Prospective cohort N=4,101	Population: -Singletons -Healthy women with no chronic conditions (hypothyroidism, heart disease, chronic kidney disease, mental illness) -Average maternal age: 32.4 years -59.9% with normal BMI (18.5-24)	Operational Definitions: -Measured daily mean temperatures from meteorological monitoring stations (01/2014-12/2017). -Daily temperature used estimate weekly temperature exposure during each participant's pregnancy via participant's residential address. Outcome Assessments: -Mean reference temperature: 23 °C. -Daily mean temperatures at 5^{th}, 25^{th}, 75^{th}, and 95^{th} percentiles of temperature distribution over 3 year period: 14, 18, 28, and 30 °C.

Key Findings

- Compared with mean temperature (23 °C), maternal temperature exposure to 28 °C (75^{th} percentile) and 30 °C (95^{th} percentile) was significantly associated with PTB risk.
- The strongest positive associations between PTB and exposure to 28 °C (75^{th} percentile) were found in the 6^{th} (HR = 1.52, *95% CI* = 1.24, 1.87, $p < 0.05$) and 24^{th} gestational weeks (HR = 1.54, *95% CI* = 1.26, 1.88, $p < 0.05$).
- The strongest positive associations between PTB and exposure to 30 °C (95th percentile) were during the 4^{th} to 8^{th} gestational weeks (HR = 1.79, *95% CI* = 1.26, 2.54, $p < 0.05$) and the 22^{nd} to 27^{th} gestational weeks (HR = 1.83, *95% CI* = 1.26, 2.62, $p < 0.05$).
- Compared to mean temperature (23 °C), maternal temperature exposure to 14 °C (5^{th} percentile) was negatively associated with risk of PTB during 2^{nd} to 10^{th}, and during the 20^{th} to 26^{th} gestational weeks. The strongest negative associations occurred at the 4^{th} (HR = 0.43, *95% CI* = 0.26, 0.72, $p < 0.05$) and 23^{rd} (HR = 0.59, *95% CI* = 0.43, 0.83, $p < 0.05$) gestational week.
- Maternal exposure to 18 °C (the 25th percentile) during the 1^{st} to 9^{th} and 20^{th} to 29^{th} gestational weeks was negatively associated with PTB risk, with the strongest negative association found during 4^{th} (HR = 0.62, *95% CI* = 0.46, 0.83, $p < 0.05$) and 23^{rd} (HR = 0.69, *95% CI* = 0.56, 0.86, $p < 0.05$) gestational week.
- Stronger temperature effects were observed among multiparous participants than among the primiparous participants. The peak positive effect was observed among multiparous participants for maternal exposure to 28 °C compared to 23 °C (HR = 1.66, *95% CI* = 1.25, 2.21, $p < 0.05$) during the 3^{rd} and 9^{th} gestational weeks; among primiparous participants, significant effects were only observed during the 5^{th} week (HR = 1.44, *95% CI* = 1.02, 1.94, $p < 0.05$).
- Exposure effects to 30 °C among multiparous participants was observed during the 6^{th} gestational week (HR = 2.13, *95% CI* = 1.31, 3.47, $p < 0.05$), however no significant effect was observed among nulliparous participants.

Wang et al., 2020	China -Humid -Tropical -Subtropical -Mostly rural	Retrospective case control N=1,281,859	Population: -Nulliparous/singleton deliveries (12/2013 - 11/2014) -Healthy pregnancy/medical history -Exclusion criteria: ethnic minority, history of PTB, multiple-gestation, pre-pregnancy disease, migration during pregnancy -94.2% rural; 5.8% urban -Delivery: 70% vaginal, 29.9% caesarean	Operational Definitions -Daily temperature records from meteorological stations -Trimesters: 1st (1-13 wks), 2nd (14-26 wks), 3rd (6 wks before delivery). -Reference temperature (12 °C) based on temperature with the min hazard ratio of PTB. Outcome Assessments: - 1st trimester average temperatures: 0 °C (threshold), 2.2 °C (5th percentile), 9.5 °C (25th percentile), 24.4 °C (74th percentile), and 28.2 °C (95th percentile) during 1st trimester. - 2nd trimester average temperatures: 0.2 °C (reference), 2.2 °C (5th percentile), 9.5 °C (25th percentile), 23.6 (75th percentile), and 27.9 °C (95th percentile) -3rd trimester average temperatures: 21.3 °C (reference), 1.2 °C (5th percentile), 8.9 °C (25th percentile), 24.0 °C (75th percentile), and 27.6 °C (95th percentile).

Key Findings • Exposure to low or high ambient temperature was associated with increased PTB risk. 1st and 2nd trimester were the most susceptible periods to high temperature effects, whereas 3rd trimester was the most susceptible period to low temperature effects, which were all significant. • The association between ambient temperature exposure and risk of PTB demonstrated a significant U-shaped curve during the entire pregnancy. • Compared to the reference temperature (12 °C), exposure to 5th percentile temperature (*HR* = 1.03, *95% CI* = 1.02, 1.04, $p < 0.05$) and 95th percentile temperature (*HR* = 1.55, *95% CI* = 1.48, 1.61, $p < 0.05$) was positively associated with PTB risk. • High temperature exposure during 1st trimester was positively associated with PTB risk in comparison to the reference temperature, with an HR of 1.75 (*95% CI* = 1.68, 1.87, $p < 0.05$) for 75th percentile temperature, and an HR of 1.95 (*95% CI* = 1.85, 2.08, $p < 0.05$) for the 95th percentile temperature. • High temperature exposure during 2nd trimester was positively associated with PTB risk, with HR of 1.41 (*95% CI* = 1.34, 1.46, $p < 0.05$) for the 75th percentile, and HR of 1.30 (*95% CI* = 1.24, 1.38, $p < 0.05$) for the 95th percentile. • Low temperature exposure during 3rd trimester was significantly associated with increased PTB risk, with HR of 1.16 (*95% CI* = 1.13, 1.20, $p < 0.05$) for the 25th percentile, and HR of 1.17 (*95% CI* = 1.12, 1.22, $p < 0.05$) for 5th percentile. • The magnitude of effects of temperature exposure during the entire pregnancy on risk of PTB varied among different subgroups based on employment and BMI. Reference temperature of pregnant participants working as farmers (11.6 °C) was lower than those working as office workers (18.3 °C). The HRs for 5th percentile and 95th percentile temperature on risk of PTB were 1.02 (*95% CI* = 1.00, 1.03, $p < 0.05$) and 1.90 (*95% CI* = 1.80, 1.99, $p < 0.05$) among participants working as farmers. In contrast, the HRs for 5th and 95th percentile temperature were lower among participants working as office workers, with respective HRs of 1.35 (*95% CI* = 1.23, 1.48, $p < 0.05$) and 1.05 (*95% CI* = 1.00, 1.10, $p < 0.05$). • The effects of temperature on participants who were overweight (BMI ≥ 24.0) were higher for 5th percentile (*HR* = 1.11, *95% CI* = 1.06, 1.16, $p < 0.05$) and 95th percentile (*HR* = 1.84, *95% CI* = 1.6, 2.04, $p < 0.05$) compared to participants with BMI range of 18.5 - 23.9 (5th percentile *HR* = 1.02, *95% CI* = 1.01, 1.04, $p < 0.05$; 95th percentile: 1.57, *95% CI* = 1.49, 1.66, $p < 0.05$).				
Kwag et al., 2021	Korea -Humid -Subtropical -Urban	Retrospective case control N=1,329,991	Population: -Singleton births (01/2010 - 12/2016) -Average maternal age: 31.8 years	Operational Definitions: -Data regarding temperature and heat wave warnings obtained from the national meteorological association. -Heat wave: maximum temperature of ≥33 °C/day lasting two or more days. -Heat wave exposure was assessed by summing the total exposure time to heat waves during each trimester, using the start and end times of the heat wave warning. -Trimesters undefined. Outcome Assessments: -Sum of heat exposure time during 1st trimester: 0 h (≤ 70th percentile), 12-57.85 h (71-80th percentile), 58-201 h (81-90th percentile) and 202.2-2,095 h (> 90th percentile).

				-The sum of heat exposure during 2nd trimester: 0 h (≤ 67th percentile), 12-62 h (68-78th percentile), 62.50-314 h (79-88th percentile) and 315 - 2,431 h (>88th percentile).
Key Findings • Exposure time to heat waves was significantly associated with higher PTB risk, after adjusting for residential area, birth year, season at birth, parity, education level of the participant, and fetal sex. • Compared with 0h of heat wave exposure, 58-201 h of heat wave exposure in 1st trimester was positively associated with PTB (*OR* = 1.05, *95% CI* = 1.01, 1.18, $p < 0.01$) and > 202.50 h of heat wave exposure in 1st trimester was positively associated with PTB (*OR* = 1.05, *95% CI* = 1.01, 1.09, $p < 0.001$). • In 2nd trimester, 62.50 - 314 h of heat wave exposure was positively associated with PTB (*OR* = 1.04, *95% CI* = 1.01, 1.07, $p < 0.05$), and >315 h of heat wave exposure was positively associated with PTB (*OR* = 1.17, *95% CI* = 1.13, 1.22, $p < 0.001$).				
Li et al., 2021	China -Humid -Subtropical -Urban	Retrospective case control N=1,388,994	Population: -All live singleton births from birth registry database (01/2003-12/2012) -Maternal age 13-50 years -Excluded cases: medically induced PTB, hysterrhexis, severe eclampsia	Operational Definitions: -Measured daily mean, min, max temperature during each trimester (2003-2012) -Intra- and inter- temperature variation (TV) measured for each gestational week and averaged for each exposure window. -Intra-day temperature variation: max diurnal temperature range (DTR), measured as daily max temperature minus daily min temperature. -Inter-day temperature variation: max difference of daily mean temperature in day t and day t-1 for each gestational week (between two days). -Positive temperature variation defined as increase in daily mean temperature between days t and t-1; negative temperature variation defined as decrease in daily mean temperature between days t and t-1. Outcome Assessments: -Daily Mean Temperature: 6-34°C -Max DTR range: 0-17°C

Key Findings

- Positive temperature variation during 1st trimester was significantly associated with PTB risk (*HR* = 1.08, *95% CI* = 1.05, 1.12, $p < 0.05$).
- Max DTR exposure during the 2nd trimester was positively associated with PTB (*HR* = 1.05, *95% CI* = 1.03, 1.08, $p < 0.05$). Higher PTB risk was associated with exposure to positive temperature variation (*HR* = 1.24, *95% CI* = 1.19, 1.28, $p < 0.05$) and to negative temperature variation (*HR* = 1.04, *95% CI* = 1.02, 1.07, $p < 0.05$) during 2nd trimester.
- Max DTR exposure during the 4 weeks before delivery was negatively associated with PTB (*HR* = 0.96, *95% CI* = 0.95, 0.97, $p < 0.05$). Positive temperature variation during the 4 weeks before delivery was positively associated with PTB (*HR* = 1.012, *95% CI* = 1.00, 1.37, $p < 0.05$), while negative temperature variation was negatively associated with PTB (*HR* = 0.99, *95% CI* = 0.97, 0.99, $p < 0.05$).
- Max DTR exposure during the week before delivery was also negatively associated with PTB (*HR* = 0.99, *95% CI* = 0.98, 0.99, $p < 0.05$). Negative temperature variation during the week before delivery was negatively associated with PTB risk (*HR* = 0.99, *95% CI* = 0.98, 0.99, $p < 0.05$).
- Temperature variation-related PTB risk was modified by season of exposure. Greater max DTR was positively associated with PTB risk in both warm (*HR* = 1.09, *95% CI* = 1.06, 1.14, $p < 0.001$) and cold seasons (*HR* = 1.13, *95% CI* = 1.08, 1.19, $p < 0.001$). Positive temperature variation was positively associated with PTB risk during the warm season (*HR* = 1.44, *95% CI* = 1.38, 1.51, $p < 0.001$), and negatively associated with PTB risk during the cold season (*HR* = 0.80, *95% CI* = 0.74, 0.86, $p < 0.001$). Negative temperature variation was positively associated with PTB risk during the warm season (*HR* = 1.14, *95% CI* = 1.09, 1.18, $p < 0.001$), and negatively associated with PTB risk during the cold season (*HR* = 0.98, *95% CI* = 0.92, 1.03, $p < 0.001$).
- Association between DTR and PTB did not vary by maternal age, parity and fetal sex. No differences were found according to early pre term, middle preterm, and late preterm outcomes. PTB risk varied according to maternal education, with the strongest association occurring between Max DTR and PTB among participants with less than high school education (*HR* = 1.05, *95% CI* = 1.04, 1.12, $p < 0.001$). A significant protective effect was found for women with postgraduate education (*HR* = 0.80, *95% CI* = 0.66, 0.97, $p < 0.001$). A higher significant effect was observed between negative temperature variation and PTB risk among participants with chronic conditions (*HR* = 1.89, *95% CI* = 1.32, 2.69, $p < 0.001$), compared to those without chronic conditions (*HR* = 1.04, *95% CI* = 1.02, 1.07, $p < 0.001$).

Table 6

Associations Between High Ambient Temperature and PTB

Authors	Positive Association			Negative Association		
	1st Trimester	2nd Trimester	3rd Trimester	1ST Trimester	2nd Trimester	3rd Trimester
He et al., 2016		X	X			
Guo et al., 2018	X	X	X			
Li et al., 2018		X	X			
Zheng et al., 2018	X		X		X	
Zhong et al., 2018	X	X				X
Wang et al., 2019	X	X				
Liu et al., 2020	X	X				
Wang et al., 2020	X	X				
Kwag et al., 2021	X	X				
Li et al., 2021	X	X				

Note. Presence of significant association between high ambient temperature and PTB risk is noted with *X*.

Table 7

Associations Between Low Ambient Temperature and PTB

Authors	Positive Association			Negative Association		
	1st Trimester	**2nd Trimester**	**3rd Trimester**	**1ST Trimester**	**2nd Trimester**	**3rd Trimester**
He et al., 2016		X	X			
Guo et al., 2018				X	X	
Li et al., 2018			X			
Zheng et al., 2018		X	X			
Liu et al., 2020				X	X	
Wang et al., 2020			X			
Li et al., 2021		X				X

Note. Presence of significant association between low ambient temperature and PTB risk is noted with *X*.

3.2 Findings

The purpose of this scoping review was to determine the effects of ambient temperature exposure on risk of PTB among pregnant women, and to identify gestational periods of vulnerability to the effects of ambient temperature exposure. The studies reviewed were published between 2016 and 2021. As the incidence of PTB is increasing globally, articles included in this review originated from different countries, as presented in Figure 2 (Vogel et al., 2019). Seven studies originated from China (*n* = 7) (He et al. 2016; Guo et al., 2018; Zheng et al., 2018; Zhong et al., 2018; Liu et al., 2020; Wang et al., 2020; Li et al., 2021), two from Australia (Li et al., 2018; Wang et al., 2019), and one from Korea (Kwag et al., 2021). No literature based out of North America, South America, or Europe met the inclusion criteria to be reviewed. All of the studies examined data from humid subtropical climate zones, with a minority also examining data from tropical zones (Guo et al., 2016; Wang et al., 2016) (see Figure 3). No studies conducted in cold climate zones (coldest month temperature is ≤ -3°C (Chen & Chen, 2013)) met the inclusion criteria to be reviewed.

All of the studies relied on data collection from health service databases and meteorological monitoring stations. The number of cases in each study ranged from 3,604 to 1,388,994. Seven of the selected studies examined the effects of low and high temperature exposure on risk of PTB, whereas three studies assessed only the effect of high temperature exposure on risk of PTB. While exact temperature ranges varied within each study, a majority of the operational definitions of temperature exposure were based on percentile ranges of temperature distributions for the specific study region and time period, collected from local meteorological monitoring stations (see Table 5). Information regarding participant demographics is presented in Table 5. Majority of the studies (*n* = 6) included cases of singleton healthy pregnant women living in urban settings (Guo et al., 2018; He et al., 2016; Kwag et al., 2021; Liu et al., 2020; Wang et al., 2019; Wang et al., 2020). Analysis was adjusted for maternal age, fetal sex, and parity in all of the studies.

Figure 2

Number of Studies by Country of Origin

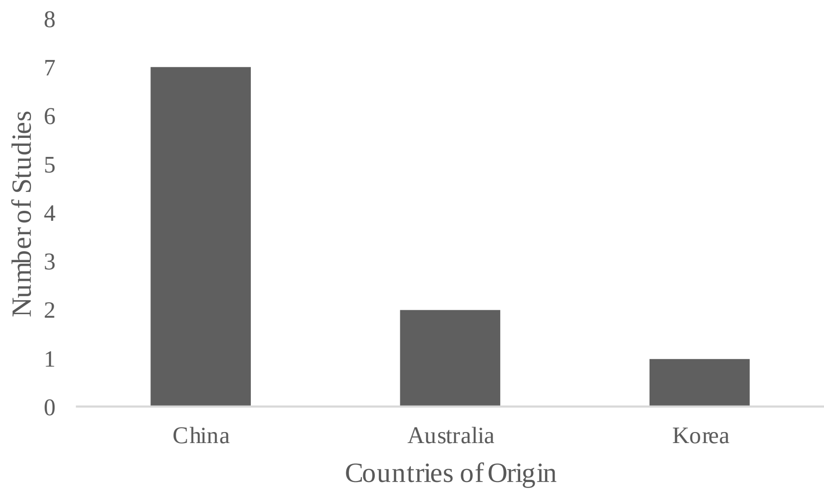
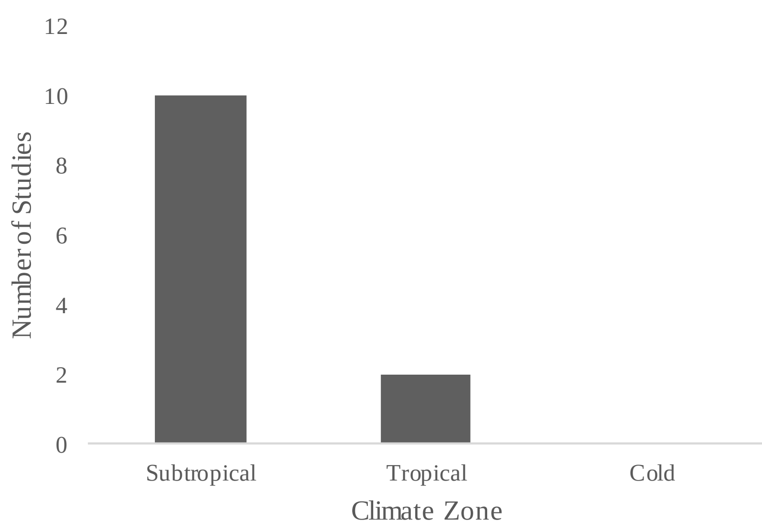


Figure 3

Number of Studies by Climate Zone



3.2.1 Effects of Ambient Temperature Exposure on Risk of Preterm Birth

Amongst the literature selected for this scoping review, various themes and discrepancies arose regarding the effects of ambient temperature exposure on risk of PTB. A U-shaped association was reported between ambient temperature exposure and risk of PTB, with exposure to relatively low and high temperatures during pregnancy significantly associated with higher risk of PTB compared to the reference temperature exposure (He et al., 2016; Li et al., 2018; Zheng et al., 2018). While Guo et al. (2018) also found high temperature exposure significantly increased the risk of PTB, they found that exposure to low temperatures reduced the risk of PTB among pregnant women. Zhong et al. (2018) found further contradicting information, reporting that exposure to extreme heat (daily temperature >90th percentile [30°C]) and higher temperatures in the second trimester increased risk of PTB, but lowered risk of PTB in the third trimester. Two other articles reported that prenatal exposure to extreme heat increased the risk of PTB (Wang et al., 2019; Kwag et al., 2021). Out of the 10 studies selected for review, only one study examined temperature variation and its effect on PTB (Li et al., 2021). Li et al. (2021) found that positive temperature variation (temperature increase of 1°C/day) increased PTB risk throughout the pregnancy, while negative temperature variations (temperature decrease of 1°C/day) increased PTB risk during the second trimester. However, negative temperature variations were also found to be associated with decreased risk of PTB during the third trimester (Li et al., 2021). See Tables 5 – 7 for a more detailed summary of study findings.

3.2.2 Gestational Periods of Susceptibility to High Temperature

Upon reviewing the selected articles, various gestational periods of susceptibility to ambient temperature exposure were identified (see Tables 5-7 for more details). He et al., (2016) reported that risk of PTB was stronger when exposure to extreme heat (≥ 30.7 °C) was during the

20th to 34th week of gestation compared to the 35th-36th weeks. In contrast, Liu et al. (2020) reported the strongest associations between high temperature exposure (mean temperature 28-30°C) and PTB risk at the sixth and 25th gestational week, along with significant associations at 4 to 8 weeks gestation and 22-27 weeks gestation. They further found stronger effects of temperature exposure on the first trimester among multiparous women compared to primiparous women (Liu et al., 2020). In contrast, Li et al. (2018) reported that gestational weeks 29 and onward were significant periods of vulnerability to the effects of high temperature (75th and 95th percentiles of temperature distribution from 1994 to 2013) exposure upon risk of PTB. Another study reported that the second trimester was a period of vulnerability for PTB risk in response to high temperature exposure (Zhong et al., 2018). Li et al. (2021) also identified the second trimester as a period of vulnerability to higher PTB risk from inter-daily temperature increase (temperature increase between days) and intra-daily temperature increase (temperature increase within a 24-hour period). Kwag et al. (2021) further identified that exposure to heat waves (≥ 33 °C lasting two or more days) during the first and second trimester significantly increased the risk of PTB.

3.2.3 Gestational Periods of Susceptibility to Low Temperature

Exposure to cold temperature was found to have a negative or positive significant association with PTB at different periods of gestation (see Table 5 for more details). Li et al. (2018) and Wang et al., (2020) found that the third trimester (gestational week 29 and onward) was susceptible to the effects of low temperature (5th and 25th percentiles of temperature) exposure on PTB risk, while Zheng et al. (2018) identified the second trimester as a period of vulnerability. Exposure to extreme cold days (<10th percentile of temperature distribution [6°C]). was also associated with an increased risk of PTB during the second and third trimester (Zheng et al., 2021). In contrast, Liu et al. (2020) found the strongest negative association between cold temperature (<14°C) and PTB risk at gestational week 4 and 23. Li et al. (2021) found that negative temperature variation increased risk of PTB during the second trimester, however reduced PTB risk during late pregnancy (1-4 weeks preceding delivery)

3.3 Summary of Findings

Ten articles were reviewed for the purpose of this SPAR project. All of the studies relied on data collection from meteorological monitoring stations. Seven of the selected studies examined the effects of low and high temperature exposure on risk of PTB, whereas three studies assessed only the effect of high temperature exposure on risk of PTB. The majority of the studies defined temperature exposure based on percentile of average temperature distribution, classifying relatively low or high temperature as falling below and above the 50th percentile of temperature distribution, respectively.

Common trends and associations were found when reviewing the articles. All of the studies found a positive association between high ambient temperature exposure and PTB risk. Of these, several studies reported a U-shaped association between ambient temperature exposure and PTB risk, with both high and low temperatures associated with higher PTB risk. However, some authors reported that exposure to lower ambient temperature was significantly associated with lower PTB risk.

The first trimester was reported as a significant period of vulnerability to the effects of high ambient temperature exposure on PTB risk. The strongest positive associations between high ambient temperature exposure and PTB risk were observed during the second trimester of pregnancy, with only one study reporting a negative association between ambient temperature exposure and PTB risk during the second trimester. Significant associations between low temperature exposure and PTB risk were reported based on exposure during the second and third trimester. Conversely, protective effects of lower temperature on PTB risk were also reported based on exposure in the first, second, and third trimester.

The following chapter further discusses the results of this scoping review in relation to the purpose of this SPAR project. Implications for nursing practice and future research recommendations are also provided.

Chapter 4: Discussion

This chapter provides a detailed discussion of the key findings from this scoping review. Gaps in the literature and areas of potential future research are also outlined. Additionally, implications for nursing practice and limitations of the findings of this scoping review are discussed.

4.1 Key Findings

4.1.1 Ambient Temperature Exposure and Risk of PTB

Various themes and contradictions arose from the literature included in this scoping review. The majority of the studies reported a significant association between exposure to heat and PTB risk.

Two studies reported that prenatal exposure to extreme heat during the first and second trimesters was associated with PTB (Wang et al., 2019; Kwag et al., 2021). Li et al. (2021) also reported a positive association between positive temperature variation (temperature increase of 1°C/ day) and PTB risk throughout the pregnancy. Two studies reported a U-shaped association between ambient temperature exposure and risk of PTB, with exposure to low and high temperatures during the second and third trimesters associated with higher risk of PTB compared to average (moderate) temperature exposure (He et al., 2016; Li et al., 2018). This relationship was observed in the urban humid, subtropical regions of China and Australia. Zhong et al. (2018) reported contradicting findings, reporting exposure to extreme heat (daily temperature > 90th percentile) and higher temperatures in the second trimester was positively associated with risk of PTB, but inversely associated with PTB risk in the third trimester. Overall, findings from these studies suggest that exposure to high temperatures during pregnancy is associated with PTB risk, yet the association between PTB and low temperature is less clear.

Guo et al. (2018)'s study, also conducted in the urban humid subtropical regions of Australia, suggested that exposure to low temperature (< 5^{th} percentile) during the first and second trimester was associated with lower PTB risk. Li et al. (2021) also found that negative temperature variation (temperature decrease of 1°C/ day) in the second trimester was associated with PTB risk during the warm season, but inversely associated with PTB risk during the cold season. Thus, perhaps the discrepancies between the various studies' reported findings were due to unaccounted seasonal patterns (differing humidity and precipitation levels), as previous literature has shown that peak PTB prevalence occurs during summer and winter (Lee et al., 2006; Woo et al., 2016)

The varying risk pattern may further be explained by the different biological mechanisms for heat-related risk of PTB (Li et al., 2021). Heat stress could potentially trigger onset of preterm labour, as well as pregnancy complications. Rapid temperature change may precipitate a thermoregulatory response in the pregnant women which includes altered placental blood flow, cortisol release, and increased circulating inflammatory mediators (Kramer et al., 2013; Ferguson et al., 2014; Li et al., 2021). Prior research has also demonstrated an association between higher corticotropin-releasing hormone (CRH) levels in the second trimester and PTB, as CRH regulates cortisol release (Ferguson et al., 2014). Heat exposure may increase cytokines and oxytocin, thus inducing labour and increasing PTB risk (He et al., 2016).

The association between cold temperature exposure and PTB risk may be attributed to various biological mechanisms (Li et al., 2021). Previous studies have demonstrated that cold temperatures could exacerbate other risk factors associated with PTB such as passive smoking, infectious agents, preeclampsia recurrence and pregnancy induced HTN (Goldenberg et al., 2008; He et al., 2016; Li et al., 2021; Muglia & Katz, 2010). Additionally, cold stress could potentially increase risk of PTB by resulting in increased blood viscosity and vascular constriction (Bruckner et al., 2014).

The discrepancy between findings could also be attributed to socioeconomic differences in population susceptibility, as well as the variety of exposure windows and statistical methods used for analysis (He et al., 2016). Specifically, women residing in different climate regions may have different temperature adaptation abilities (Guo et al., 2018; Li et al., 2021). As well, Li et al.'s (2021) findings suggest that higher education levels may be related to greater adaptation to temperature exposure among pregnant women. However, additional studies are needed to clarify the pathways explaining the associations between temperature exposure, SES, education, and PTB. However, the underlying mechanisms explaining the association between ambient temperature exposure and PTB risk require further investigation to allow clearer characterization of their risks to pregnant women. Additional factors will be discussed in detail in the next section of this chapter.

4.1.2 Gestational Periods of Vulnerability to Effects of High Temperature Exposure

Upon reviewing the selected articles, various gestational periods of susceptibility to high ambient temperature exposure were identified (See Tables 5-6 for more details). Based on the studies of this scoping review, the second trimester was the most commonly reported period of vulnerability to the effects of high temperature exposure.

First Trimester. Eight studies identified the first trimester as a period of vulnerability to heat exposure (See Table 6). Liu et al. (2020) reported the strongest associations between high ambient temperature exposure (mean temperature 28-30°C) and PTB risk at the sixth gestational week, along with significant associations at 4 to 8 weeks gestation. They further found stronger effect of temperature exposure on the first trimester among multiparous women compared to primiparous women (Liu et al., 2020). Kwag et al. (2021) further reported that exposure to heat waves (≥ 33°C lasting two or more days) during the first trimester was significantly associated with higher PTB risk.

Second Trimester. The second trimester was the most commonly reported period of vulnerability to the effects of high temperature exposure (See Table 6). Liu et al., (2020) reported the strongest association between high temperature exposure and PTB risk at the 25th gestational week, along with significant associations at 22-27 weeks gestation. Three other studies reported that the second trimester was a period of vulnerability for PTB risk in response to high temperature exposure (Li et al., 2018; Kwag et al., 2021; Zhong et al., 2018). Specifically, Kwag et al. (2021) reported that exposure to heat waves (≥ 33°C lasting two or more days) during the second trimester was significantly associated with higher PTB risk. Li et al. (2021) further identified the second trimester as a period of vulnerability to higher PTB risk from inter-daily temperature increase (temperature increase between days) and intra-daily temperature increase (temperature increase within a 24-hour period).

Third Trimester. Four studies identified the third trimester as a period of susceptibility to effects of heat exposure on PTB risk (Guo et al., 2018; He et al., 2016; Li et al., 2018; Zheng et al., 2018). He et al., (2016) reported that risk of PTB was stronger when exposure to extreme heat (≥ 30.7 °C) was during the 20th to 34th week of gestation compared to the 35th-36th weeks. Li et al. (2018) reported that gestational weeks 29 and onward were significant periods of vulnerability to the effects of high temperature (75th and 95th percentiles of temperature distribution from 1994 to 2013) exposure upon risk of PTB.

Physiological Mechanisms. Various factors impact thermoregulation ability during pregnancy, including state of acclimatization and level of hydration (Olivier et al., 2020).

Previous studies indicate that the first and second trimester are potential periods of vulnerability to heat stress, as the developing placenta and fetus increase metabolic heat, thus increasing thermoregulation demands (Olivier et al., 2020). Increase in blood volume during pregnancy optimizes heat transfer and dissipation, supporting adaptability to heat exposure (Olivier et al., 2020). Thus, these physiological adaptations during pregnancy may explain why pregnant women are more vulnerable to effects of heat exposure during this particular gestational window compared to the third trimester. However, additional studies are needed to investigate this possible mechanism explaining these periods of vulnerability.

4.1.3 Gestational Periods of Vulnerability to Effects of Low Temperature Exposure

Exposure to cold temperature was found to have a negative or positive association with PTB risk depending on periods of gestation (see Tables 5 and 7 for more details). Liu et al. (2020) found the strongest negative association between cold temperature (<14°C) and PTB risk at gestational week 4 and 23. Zheng et al., (2018) and Li et al., (2020) also identified the second trimester as a period of vulnerability. Li et al. (2020) specifically reported that negative temperature variations during the second trimester were associated with increased PTB risk. Exposure to extreme cold days (<10th percentile of temperature distribution [6°C]) was also associated with an increased risk of PTB during the second trimester (Zheng et al., 2021). Only one study identified that exposure to extreme cold (<6°C) was associated with increased PTB risk during the third trimester (Zheng et al., 2021). In contrast, Li et al., (2021) found that negative temperature variations were associated with lower PTB risk during late pregnancy (1-4 weeks preceding delivery), and Liu et al., (2018) found that lower ambient temperature was associated with lower PTB risk during the first and second trimester. An increase in pregnancy-related fat deposition and decrease in body surface area to body weight ratio during pregnancy may account for why women are less susceptible to cold temperatures during late pregnancy as opposed to earlier in the pregnancy, however, more research is needed to confirm this mechanism (Liu et al., 2020).

4.2 Gaps in the Literature and Suggestions for Future Research

Several gaps were identified when reviewing the selected studies, including a lack of data regarding study location, level of urbanicity, and other potential covariates. Future research priorities are recommended in order to address this gap in the literature.

4.2.1 Location

A majority of studies were conducted in China, with two in Australia and one in Korea. No literature based out of North America, South America, or Europe met the inclusion criteria to be reviewed. Additionally, all of the studies examined data from humid subtropical climate zones, with a minority examining data from tropical zones. No studies conducted in cold or dry climate zones met the inclusion criteria to be reviewed.

This gap potentially limits the generalizability and applicability of the findings to populations based in North America, South America, or Europe, or those living in cold or dry climate zones. Specifically, women residing in different climates may have different temperature adaptation abilities (Guo et al., 2018; Li et al., 2021). This has implications as it is unclear whether the associations observed between temperature exposure and PTB risk would occur in different climate zones, or whether the different climate zone would potentially moderate or mediate the effects.

Importantly, all of the studies were conducted in high-income developed countries. None of the studies were conducted in low- or middle-income countries, which account for a majority of the global PTB burden (Vogel et al., 2018). In addition to being disproportionately affected by

PTB mortality and morbidity, low- and middle- income countries are also vulnerable to the negative impacts of extreme heat due to insufficient resources to adapt to or mitigate the effects of climate-change on health (Nicholas & Breakey, 2017; Roos et al., 2021; Rylander et la., 2013). Pregnant women in developing countries are also at higher risk of exposure to temperature extremes due to lack of air conditioning or central heating, and more physical working conditions (Beltran et al., 2013; He et al., 2016; Rylander et al., 2013). Thus, further research is warranted in low- and middle-income countries to identify whether current evidence can be replicated in these contexts.

4.2.2 Urbanicity

The majority of the studies examined cases of singleton healthy pregnant women living in urban settings. While two of the studies included cases of rural pregnant women in China, their results were conflicting, with Guo et al., (2018) reporting an inverse association between cold temperature exposure and PTB risk, and Wang et al. (2020) reporting a U-shaped association between temperature exposure and PTB risk. In some countries, women living in rural areas are more vulnerable to PTB risk due to poor living conditions and inadequate access to medical facilities compared to those living in urban settings, thus these factors would need to be considered when evaluating the link between temperature exposure and risk of PTB (Li et al., 2020; Luo & Wilkins, 2008). Conversely, urban women may be increasingly vulnerable to the effects of air pollution (particulate matter) on PTB risk (Li et al., 2020). However, women living in urban settings may have more access to air conditioners and prenatal services, potentially mediating the effects of ambient temperature exposure on PTB (Li et al., 2020; Luo & Wilkins, 2008). The studies included in this scoping review do not compare or contrast participants from rural settings to those from urban settings. Thus, it is unclear whether the effects of ambient temperature exposure on PTB would be stronger or weaker among rural populations. Furthermore, there are no data provided regarding the participants' access or utilization of air conditioning or heating, which may potentially mitigate the effects of heat on PTB risk. Thus, further research is needed among rural populations to clarify the relationship between temperature exposure and PTB risk taking into account possible confounding factors such as living conditions.

4.2.3 Potential Covariates and Subgroups

Common covariates which were adjusted for in each study included parity, maternal age, and fetal sex However, there was inconsistency in the consideration of potential covariates such as education, socioeconomic status (SES), nutrition, body-mass index (BMI), and activity level, as well as the multicollinearity among these variables.

Smoking. Exposure to smoking was adjusted for in a few studies included in this scoping review (Li et al., 2018; Liu et al., 2020; Wang et al., 2020). Maternal smoking and exposure to second-hand smoke during pregnancy are associated with increased PTB risk (Forray, 2016; Medley et la., 2018; Vogel et al., 2018). , However, the majority of the studies in this review did not include smoke exposure in their analyses.

Education. Additionally, only four studies included adjustment for the effects of maternal education (He et al., 2016; Kwag et al., 2021; Liu et al., 2020; Wang et al., 2020). Lower maternal education has been associated with increased PTB risk (Kumar et al., 2017; McHale et al., 2021; Ruiz et al., 2015; Vogel et al., 2018). Thus, it is unclear whether the findings of the remaining studies would be altered if taking maternal education status into account. Li et al. (2021)'s findings also suggest that higher education levels may be related to greater ability to adapt to temperature exposure among pregnant women, however, further research is needed to confirm this connection.

Socioeconomic status. Education level and socioeconomic status are highly correlated variables; however, SES was only accounted for in three studies included in this scoping review by adjusting for household income level (Liu et al., 2020; Zheng et al., 2018; Zhong et al., 2018). Lower income is a well-known risk factor for PTB risk (Kumar et al, 2017; McHale et al., 2021; Vogel et al., 2018); however, it was not adjusted for in the remaining studies of the scoping review. Thus, further research is warranted to investigate whether socioeconomically disadvantaged populations are more vulnerable to the effects of ambient temperature exposure on PTB risk.

Nutrition. Lui et al. (2020) adjusted for nutritional intake in their analysis, specifically adjusting for vitamin, vegetable, meat, and tea consumption. Maternal nutrition places a significant role in influencing risk of PTB, specifically as vitamin D insufficiency is associated with early and late preterm birth, and omega-3 fatty acid supplementation is associated with reduced PTB risk (Amegah et al., 2017; Bloomfield, 2011; de Seymour et al., 2019; Vogel et al., 2018). The remaining studies did not include data regarding maternal nutrition status nor adjust for this variable in their analyses.

Activity. Maternal activity level is another potential confounder that influences PTB risk, as leisure time physical activity is associated with reduced risk of PTB (Aune et al., 2018; Kahn et al., 2016; Raper et al., 2021). However, increased indoor and outdoor activities may result in increased vulnerability to the changes in external temperature, thus exacerbating PTB risk (Rylander et al., 2013). Yet, none of the studies in this scoping review collected data regarding maternal activity or adjusted for it in their analysis. Thus, it is unclear how the effects of ambient temperature exposure on PTB risk may be influenced by the level of maternal activity.

Occupation. Maternal occupational status is a relevant confounder which was also adjusted for in two studies within this scoping review (Zhong et al., 2018; Wang et al., 2020). Wang et al. (2020) reported stronger effects of ambient temperature on PTB risk among participants who were farmers compared to office workers. The farmers were perhaps more vulnerable to the effects of ambient temperature exposure and particulate matter pollution from prolonged outdoor exposure, compared to the office workers (Rylander et al., 2013; Vogel et al., 2018; Wang et al., 2020). However, no data were provided regarding hours worked or daytime/nighttime shiftwork among participants. Shift work and working long hours (>40 hours/week) compared to standard hours (≤40 hours/week) has been found to increase PTB risk (Cai et al., 2019). Occupation-related stress was also not accounted for in any of the studies. Further studies are warranted to investigate whether shift workers or certain occupational groups are more vulnerable to the risks of ambient temperature exposure on risk of PTB

Body Mass Index. Pre-pregnant body mass index (BMI) was adjusted for in only three studies within this scoping review (Guo et al., 2018, Liu et al., 2020, Wang et al., 2020). Wang et al., (2020) reported a higher effect of low and high ambient temperature exposure on PTB risk among women who were overweight (BMI range ≥ 24.0) compared to those with normal weight (BMI = 18.5 – 23.9). Thus, these findings suggest that overweight women may be more vulnerable to the effects of ambient temperature exposure on PTB risk. However, high BMI is related to various adverse pregnancy complications such as gestational diabetes, preeclampsia, and pregnancy-induced hypertension, which are known risk factors for PTB (Pigatti Silva et al., 2019). Because the remaining studies in the scoping review did not include BMI in their data collection, no conclusion can be made at this point. Further research is needed to investigate this relationship and account for potential confounders associated with high BMI.

Medical and Obstetrical History. Only a few studies included information regarding maternal medical/obstetrical history within the analyses (Li et al., 2018; Liu et al., 2020; Li et al., 2021). High risk obstetrical conditions such as preeclampsia, gestational hypertension, and gestational diabetes increase the risk of PTB (Vogel et al. 2018). Previous research suggests that cold temperatures could increase occurrence of preeclampsia and pregnancy induced HTN via increased vasoconstriction, thus potentially exacerbating the risk of PTB (Goldenberg et al., 2008; Muglia & Katz, 2010). The majority of the studies in this scoping review included only healthy pregnant women. Further research is needed to investigate in at-risk pregnancies the relationship between ambient temperature exposure and PTB risk.

4.3 Implications for Nursing Practice in British Columbia

4.3.1 Implications for Perinatal Nursing Practice and Risk Communication

Although the articles in this scoping review did not detail the role of nurses, there are various implications from these study findings that can be applied to nursing practice at various levels. Specific nursing implications are relevant for direct care, client/community education and risk communication, nursing education, and health policy development (Neal-Boylan et al., 2019; Nicholas & Breakey, 2017).

Increasing awareness about the effects of climate change on maternal health outcomes has been prioritized among professional health organizations (Adebayo et al., 2020). Despite this, many women lack knowledge regarding the perinatal risks of temperature exposure and appropriate protective behaviors to mitigate these risks (Adebayo et la., 2020). The results of this scoping review may support public health and antepartum nurses in providing adequate counselling and education to pregnant women to mitigate the risk of PTB in relation to temperature exposure. Client education should include education on risks and strategies to mitigate heat stress (McDermott-Levy et al., 2019; Roos et al., 2021). Nurses can educate clients on strategies to adjust to higher ambient temperature such as seeking shade, indoor shelter, taking frequent breaks, use of air conditioning/fans, and staying hydrated (Rylander et al., 2013). Education materials and pamphlets about harms of heat exposure during the prenatal period can increase client knowledge and self-efficacy in ability to perform self-protective actions (Adebayo et al., 2020). Nurses can play a key role in reducing client vulnerability to risks by educating pregnant women to reduce outdoor activities during extreme temperatures (McDermott-Levy et al., 2019). Relevant health promotion and risk reduction initiatives can be delivered by perinatal and public health nurses in various settings, including community prenatal classes, and outpatient and inpatient discharge teaching sessions. Client education would particularly be targeted at clients in their second trimester as these were identified as potential periods of vulnerability within this scoping review. Thus, nurses are well posited to serve as knowledge sources for clients and communities in order to promote climate mitigation, adaptation, and resilience strategies (Leffers et al., 2017).

4.3.2 Role of Advocacy and Policy Development

The nursing profession is also well positioned to advocate for policies to mitigate climate change. Nurses may utilize the findings of this scoping review in order to champion health promotion initiatives to address the perinatal health impacts of extreme temperature exposure related to climate change (Kalogriou et al., 2020; Nicholas & Breakey, 2017). Efforts are required to raise awareness among policy makers regarding consequences of climate change on perinatal health, and efficient heat mitigation interventions and head adaptation planning to the most affected and least resilient settings and populations (Roos et al., 2021; Rylander et al., 2013). The nursing profession can play a key role in disseminating papers and position statements about nursing's health policy work related to climate change (Hanley et al., 2016; Nicholas & Breakey, 2017). Nurses can advocate on behalf of populations vulnerable to the effects of climate change related temperature effects, such as pregnant women. Future research is recommended in order to investigate the effectiveness of nursing interventions aimed at mitigating and adapting to the perinatal health effects of temperature exposure (Nicholas & Breakey, 2017).

4.3.3 Implications for Nursing Education/Curriculum

The insights gleaned from this scoping review may support the development of environmental health nursing curriculum in nursing education programs, which has been mandated as priority areas for nursing curriculum by the Canadian Nurses Association, the Canadian Association of Nurses for the Environment and various nursing leaders and scholars (Canadian Nurses Association, 2017; Kalogirou et la., 2020; Leffers et al., 2017). Effective training should prepare nursing graduates to implement the principles of mitigation, adaptation, and resilience to address climate-related temperature effects on human health (McDermott-Levy et al., 2019; Neal-Bolan et al., 2019; Sullivan-Marx & McCauley, 2017). In order to embed climate-change related education in all levels of nursing education, theoretical frameworks must be integrated into the curriculum to guide nursing approaches to mitigating effects of climate change on health (Sullivan- Marx & McCauley, 2017). Based on the findings of this scoping review, it is recommended to include content regarding the relationship between ambient temperature risk and PTB risk, and potential mitigating strategies within BSN and specialty perinatal training programs

4.4 Limitations

Some limitations were identified while completing this SPAR project. There was a limited number of articles that met the inclusion criteria. The majority of the articles originated from Asia, with no articles from North America, South America, Europe, or Southeast Asia. None of the articles that met the selection criteria were Canadian-based; no national data examining the relationship between ambient temperature exposure and PTB risk. Although sample sizes were substantial in many studies, important covariates and known PTB risk factors were not accounted for within the analyses. Thus, the findings of these studies should be interpreted with consideration to these limitations. There were also limitations in the level of evidence amongst the studies included in this scoping review. No systematic reviews met inclusion criteria. As this project is a narrative review of the evidence, there is a potential for subjectivity when selecting and analyzing studies, however, specific inclusion/ exclusion criteria and systematic search strategies were utilized to reduce the risk for bias. Additionally, only articles that were available or published in English were included in this scoping review, which may have eliminated non-English articles that could have contributed to answering the research questions of this project.

4.5 Conclusions

The literature in this scoping review investigated the association between ambient temperature exposure during different gestational periods on risk of PTB, and identified potential gestational periods of vulnerability. The articles reviewed were all quantitative studies, including retrospective case control studies and prospective cohort studies. Various associations were reported but similar themes could be identified amongst the gestational periods of vulnerability. The overall findings suggest that exposure to high ambient temperature during the first and second trimester is associated with an increased risk of PTB. Exposure to low ambient temperature during different trimesters was found to be associated with lower and higher risk of PTB, and warrants further investigation.

PTB rates were higher among those that were of higher BMI, lower maternal education levels, and farm workers, irrespective of temperature exposure. Thus, it is important to consider these risk factors, as well as the potentially moderating/mediating effects that women's educational background and pre-pregnancy BMI may play in their vulnerability to the effects of temperature exposure on PTB risk. There were gaps in the current literature and areas requiring further research, particularly regarding lack of data regarding potential confounders and maternal characteristics. The majority of participants were those with healthy singleton pregnancies, living in urban settings in developed countries. Populations living in rural or remote regions, with lower SES and at-risk medical/obstetrical conditions remain understudied within this area of research.

The findings of this scoping review have various implications for nursing practice, as it is within a perinatal nurse' scope to educate, support, and counsel pregnant women regarding risk factors for preterm birth (British Columbia College of Nurses and Midwives [BCCNM], 2021). Registered nurses are particularly well situated to provide effective client education regarding risks of temperature exposure and mitigating strategies to perinatal clients via community prenatal classes, and individualized client counselling during outpatient and inpatient care settings. The nursing profession is also well positioned to advocate for policies to address the health effects of ambient temperature exposure on pregnant women, and to advocate for cost-effective mitigating strategies for vulnerable populations. In order to ensure nurses are adequately trained to educate and advocate for clients, it is imperative for nurse educators to educate nursing students on the impacts of climate change on perinatal health, and to develop specific curriculum to support these learning objectives. Specifically, the relationship between ambient temperature exposure and PTB risk can be included as an educational example of the effects of climate change on vulnerable or at-risk populations. Future nursing research is recommended to investigate the effectiveness of nursing lead initiatives to mitigate the effects of ambient temperature exposure on PTB risk.

References

Adebayo, A. L., Davidson Mhonde, R., DeNicola, N., & Maibach, E. (2020). The effectiveness of narrative versus didactic information formats on pregnant women's knowledge, risk perception, self-efficacy, and information seeking related to climate change health risks. International *Journal of Environmental Research and Public Health, 17*(19), 1. https://doi.org/10.3390/ijerph17196969

Amegah, A. K., Klevor, M. K., & Wagner, C. L. (2017). Maternal vitamin D insufficiency and risk of adverse pregnancy and birth outcomes: A systematic review and meta-analysis of longitudinal studies. *PloS One, 12*(3), e0173605-e0173605. https://doi.org/10.1371/journal.pone.0173605

Aune, D., Schlesinger, S., Henriksen, T., Saugstad, O. D., & Tonstad, S. (2018). Physical activity and the risk of preterm birth: A systematic review and meta-analysis of epidemiological studies. *Obstetric Anesthesia Digest, 38*(3), 120-120. https://doi.org/10.1097/01.aoa.0000542336.05772.f1

British Columbia College of Nurses and Midwives (2021). *Scope of practice for registered nurses.* https://www.bccnm.ca/Documents/standards_practice/lpn/LPN_ScopeOfPractice.pdf

British Columbia Reproductive Care Program. (2005). Obstetric guideline 2A: Preterm labour. *Perinatal Services British Columbia*. [Obstetric guideline 2A]. http://www.perinatalservicesbc.ca/Documents/Guidelines-Standards/Maternal/PretermLabourGuideline.pdf

Canadian Nurses Association. (2017). *Climate change and health position statement.* https://www.cna-aiic.ca/-/media/cna/page-content/pdf-en/climate-change-and-health-position-statement.pdf?la=en&hash=5E757EEDA69508F4EEBF797902D6F843E4407EA4

Cai, C., Vandermeer, B., Khurana, R., Nerenberg, K., Featherstone, R., Sebastianski, M., & Davenport, M. H. (2019). The impact of occupational shift work and working hours during pregnancy on health outcomes: a systematic review and meta-analysis. *American Journal of Obstetrics and Gynecology, 221*(6), 563-576. https://doi.org/10.1016/j.ajog.2019.06.051

de Seymour, J. V., Simmonds, L. A., Gould, J., Makrides, M., & Middleton, P. (2019). Omega-3 fatty acids to prevent preterm birth: Australian pregnant women's preterm birth awareness and intentions to increase omega-3 fatty acid intake. *Nutrition Journal, 18*(1), 74-74. https://doi.org/10.1186/s12937-019-0499-2

El-Mazahi, M. M., El-Mahdi, M. A. E., El-Khaleeg, Hani Abd El- Hadi, & Abou Gomaa, G. H. (2014). Cognitive and behavioural outcome of preterm versus full term infants, at school entry age. *Trends in Medical Research, 9*(1), 44-52. https://doi.org/10.3923/tmr.2014.44.52

Ferguson, K. K., McElrath, T. F., Chen, Y., Mukherjee, B., & Meeker, J. D. (2014). Longitudinal profiling of inflammatory cytokines and C-reactive protein during uncomplicated and preterm pregnancy. *American Journal of Reproductive Immunology (1989), 72*(3), 326-336. https://doi.org/10.1111/aji.12265

Frey, H. A., & Klebanoff, M. A. (2016). The epidemiology, etiology, and costs of preterm birth. *Seminars in Fetal & Neonatal Medicine, 21*(2), 68-73. https://doi.org/10.1016/j.siny.2015.12.011

Forray, A. (2016). Substance use during pregnancy. *F1000 Research, 5*, 887.

https://doi.org/10.12688/f1000research.7645.1

Garrard, J. (2017). *Health sciences literature review made easy: The matrix method* (5th ed.). Jones & Bartlett Learning.

George, M., Bruzzese, J., & Matura, L. A. (2017). Climate change effects on respiratory health: Implications for nursing. *Journal of Nursing Scholarship, 49*(6), 644-652. https://doi.org/10.1111/jnu.12330

Giudice, L. C., Llamas-Clark, E. F., DeNicola, N., Pandipati, S., Zlatnik, M. G., Decena, D. C. D., Woodruff, T. J., & Conry, J. A. (2021). Climate change, women's health, and the role of obstetricians and gynecologists in leadership. *International Journal of Gynecology and Obstetrics, 155*(3), 345-356. https://doi.org/10.1002/ijgo.13958

Guo, T., Wang, Y., Zhang, H., Zhang, Y., Zhao, J., Wang, Y., Xie, X., Wang, L., Zhang, Q., Liu, D., He, Y., Yang, Y., Xu, J., Peng, Z., & Ma, X. (2017). The association between ambient temperature and the risk of preterm birth in china. *The Science of the Total Environment, 613-614*, 439-446. https://doi.org/10.1016/j.scitotenv.2017.09.104

Hanley, F., Bogart, B. H., Milburn, M., & Stafford, L. (2016). Nursing and climate change: The time to act is now!(role of nurses in the health impacts of climate change). *Info Nursing (English Ed.), 47*(1), 32.

Hanneke, R., Asada, Y., Lieberman, L., Neubauer, L. C., Fagen, M., & SAGE Research Methods Complete A-Z List. (2017). *The scoping review method: Mapping the literature in "structural change" public health interventions*. SAGE Publications Ltd.

Harrison, M. S., & Goldenberg, R. L. (2016). Global burden of prematurity. *Seminars in fetal & neonatal medicine*, *21*(2), 74–79. https://doi.org/10.1016/j.siny.2015.12.007

He, J., Liu, Y., Xia, X., Ma, W., Lin, H., Kan, H., Lu, J., Feng, Q., Mo, W., Wang, P., Xia, H., Qiu, X., & Muglia, L. J. (2016). Ambient temperature and the risk of preterm birth in guangzhou, china (2001-2011). *Environmental Health Perspectives, 124*(7), 1100-1106. https://doi.org/10.1289/ehp.1509778

Johnston, K.M., Gooch, K., Korol, E. et al. The economic burden of prematurity in Canada. BMC Pediatr 14, 93 (2014). https://doi.org/10.1186/1471-2431-14-93

Joseph, K. S., Huang, L., Liu, S., Ananth, C. V., Allen, A. C., Sauve, R., Kramer, M. S., & Fetal and Infant Health Study Group of the Canadian Perinatal Surveillance System. (2007). Reconciling the high rates of preterm and postterm birth in the united states. *Obstetrics and Gynecology (New York. 1953), 109*(4), 813-822. https://doi.org/10.1097/01.AOG.0000255661.13792.c1

Kahn, M., Robien, K., & DiPietro, L. (2016). Maternal leisure-time physical activity and risk of preterm birth: A systematic review of the literature. *Journal of Physical Activity & Health, 13*(7), 796-807. https://doi.org/10.1123/jpah.2015-0495

Kalogirou, M. R., Dahlke, S., Davidson, S., & Yamamoto, S. (2020). Nurses' perspectives on climate change, health and nursing practice. *Journal of Clinical Nursing, 29*(23-24), 4759-4768. https://doi.org/10.1111/jocn.15519

Kramer, M. S., Lydon, J., Goulet, L., Kahn, S., Dahhou, M., Platt, R. W., Sharma, S., Meaney, M. J., & Séguin, L. (2013). Maternal Stress/Distress, hormonal pathways and spontaneous preterm birth: *Stress hormones and preterm birth. Paediatric and Perinatal Epidemiology, 27*(3), 237-246. https://doi.org/10.1111/ppe.12042

Kwag, Y., Kim, M., Oh, J., Shah, S., Ye, S., & Ha, E. (2021). Effect of heat waves and fine particulate matter on preterm births in korea from 2010 to 2016. *Environment International, 147*, 106239. https://doi.org/10.1016/j.envint.2020.106239

Lee, S., Steer, P., & Filippi, V. (2006). Seasonal patterns and preterm birth: A systematic review of the literature and an analysis in a london-based cohort. BJOG : An International Journal of Obstetrics and Gynaecology, 113(11), 1280-1288. https://doi.org/10.1111/j.1471-0528.2006.01055.x

Leffers, J., Levy, R. M., Nicholas, P. K., & Sweeney, C. F. (2017). Mandate for the nursing profession to address climate change through nursing education. *Journal of Nursing Scholarship, 49*(6), 679-687. https://doi.org/10.1111/jnu.12331

Li, S., Chen, G., Jaakkola, J. J. K., Williams, G., & Guo, Y. (2018). Temporal change in the impacts of ambient temperature on preterm birth and stillbirth: Brisbane, 1994–2013. *The Science of the Total Environment, 634*, 579-585. https://doi.org/10.1016/j.scitotenv.2018.03.385

Li, L., Ma, J., Cheng, Y., Feng, L., Wang, S., Yun, X., & Tao, S. (2020). Urban-rural disparity in the relationship between ambient air pollution and preterm birth. *International Journal of Health Geographics, 19*(1), 23-15. https://doi.org/10.1186/s12942-020-00218-0

Li, C., Bloom, M. S., Lin, S., Ren, M., Hajat, S., Wang, Q., Zhang, W., Ho, H. C., Zhao, Q., Lin, Y., & Huang, C. (2021). Temperature variation and preterm birth among live singleton deliveries in shenzhen, china: A time-to-event analysis. *Environmental Research, 195*, 110834. https://doi.org/10.1016/j.envres.2021.110834

Liu, X., Xiao, J., Sun, X., Chen, Q., Yao, Z., Feng, B., Cao, G., Guo, L., He, G., Hu, J., Zeng, W., Rong, Z., Wang, Q., Zhang, B., Dong, M., Wang, J., Chen, D., Ma, W., & Liu, T. (2020). Associations of maternal ambient temperature exposures during pregnancy with the risk of preterm birth and the effect modification of birth order during the new baby boom: A birth cohort study in guangzhou, china. *International Journal of Hygiene and*

Environmental Health, *225*, 113481. https://doi.org/10.1016/j.ijheh.2020.113481

Luo, Z., & Wilkins, R. (2008). Degree of rural isolation and birth outcomes. *Paediatric and Perinatal Epidemiology*, *22*(4), 341-349. https://doi.org/10.1111/j.1365-3016.2008.00938.x

McDermott-Levy, R., Jackman-Murphy, K. P., Leffers, J. M., & Jordan, L. (2019). Integrating climate change into nursing curricula. *Nurse Educator*, *44*(1), 43-47. https://doi.org/10.1097/NNE.0000000000000525

McHale, P., Maudsley, G., Pennington, A., Schlüter, D., Barr, B., Paranjothy, S., & Taylor-Robinson, D. (2021). OP43 Mediators of socioeconomic differences in preterm birth: A systematic review of the evidence. *Journal of Epidemiology and Community Health*, *75*, A20. https://doi.org/10.1136/jech-2021-SSMabstracts.43

Medley, N., Vogel, J. P., Care, A., & Alfirevic, Z. (2018). Interventions during pregnancy to prevent preterm birth: An overview of cochrane systematic reviews. *Cochrane Database of Systematic Reviews*, *11*, CD012505-CD012505. https://doi.org/10.1002/14651858.CD012505.pub2

Muglia, L. J., & Katz, M. (2010). The enigma of spontaneous preterm birth. *The New England Journal of Medicine*, *362*(6), 529-535. https://doi.org/10.1056/NEJMra0904308

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology, 18(1), 143-143. https://doi.org/10.1186/s12874-018-0611-x

Neal-Boylan, L., Breakey, S., & Nicholas, P. K. (2019). Integrating climate change topics into nursing curricula. *The Journal of Nursing Education*, *58*(6), 364-368.

https://doi.org/10.3928/01484834-20190521-09

Nicholas, P. K., & Breakey, S. (2017). Climate change, climate justice, and environmental health: Implications for the nursing profession: Climate change and environmental health. *Journal of Nursing Scholarship, 49*(6), 606-616. https://doi.org/10.1111/jnu.12326

Olivier, K., Reinders, L. A., Clarke, M. W., Crew, R. C., Pereira, G., Maloney, S. K., & Wyrwoll, C. S. (2020;2021;). Maternal, placental, and fetal responses to intermittent heat exposure during late gestation in mice. *Reproductive Sciences, 28*(2), 416-425. https://doi.org/10.1007/s43032-020-00291-7

Peters, A., & Schneider, A. (2021;2020;). Cardiovascular risks of climate change. *Nature Reviews Cardiology, 18*(1), 1-2. https://doi.org/10.1038/s41569-020-00473-5

Pigatti Silva, F., Souza, R. T., Cecatti, J. G., Passini, J., Renato, Tedesco, R. P., Lajos, G. J., Nomura, M. L., Rehder, P. M., Dias, T. Z., Oliveira, P. F., Silva, C. M., & Brazilian Multicenter Study on Preterm Birth (EMIP) study group. (2019). Role of body mass index and gestational weight gain on preterm birth and adverse perinatal outcomes. *Scientific Reports, 9*(1), 13093-12. https://doi.org/10.1038/s41598-019-49704-x

Public Health Agency of Canada. (2017). Canadian Perinatal Health Report. 2017. Ottowa.

Polit, D., & Beck, C. (2020). *Nursing research*. Wolters Kluwer Health.

Raper, M. J., McDonald, S., Johnston, C., Isler, C., Newton, E., Kuehn, D., Collier, D., Broskey, N. T., Muldrow, A., & May, L. E. (2021). The influence of exercise during pregnancy on racial/ethnic health disparities and birth outcomes. *BMC Pregnancy and Childbirth, 21*(1), 258-258. https://doi.org/10.1186/s12884-021-03717-5

Rios, J. D., Beltempo, M., Louis, D., Premji, S., Shah, V., Lee, S. K., Pechlivanoglou, P., Abenhaim, H., Afifi, J., Alvaro, R., Andrews, J., Armson, A., Aziz, K., Barrett, J., Berard, A., Bertelle, V., Bodani, J., Burrows, J., Butt, K., . . . Canadian Neonatal Network Investigators. (2021). Costs of neonatal intensive care for canadian infants with preterm birth. *The Journal of Pediatrics, 229*, 161-167.e12. https://doi.org/10.1016/j.jpeds.2020.09.045

Roos, N., Kovats, S., Hajat, S., Filippi, V., Chersich, M., Luchters, S., Scorgie, F., Nakstad, B., Stephansson, O., Hess, J., Kadio, K., Kouanda, S., Lusambili, A., Marsham, J., Ngugi, A., Wright, C. Y., & CHAMNHA Consortium. (2021). Maternal and newborn health risks of climate change: A call for awareness and global action. *Acta Obstetricia Et Gynecologica Scandinavica, 100*(4), 566-570. https://doi.org/10.1111/aogs.14124

Ruiz, M., Goldblatt, P., Morrison, J., Kukla, L., Švancara, J., Riitta-Järvelin, M., Taanila, A., Saurel-Cubizolles, M., Lioret, S., Bakoula, C., Veltsista, A., Porta, D., Forastiere, F., van Eijsden, M., Vrijkotte, T. G. M., Eggesbø, M., White, R. A., Barros, H., Correia, S., . . . Pikhart, H. (2015). Mother's education and the risk of preterm and small for gestational age birth: A DRIVERS meta-analysis of 12 european cohorts. *Journal of Epidemiology and Community Health (1979), 69*(9), 826-833. https://doi.org/10.1136/jech-2014-205387

Rylander, C., Øyvind Odland, J., & Manning Sandanger, T. (2013). Climate change and the potential effects on maternal and pregnancy outcomes: An assessment of the most vulnerable - the mother, fetus, and newborn child. *Global Health Action*, *6*(1), 19538-9. https://doi.org/10.3402/gha.v6i0.19538

Sorensen, C., Murray, V., Lemery, J., & Balbus, J. (2018). Climate change and women's health: Impacts and policy directions. *PLoS Medicine*, *15*(7), e1002603-e1002603. https://doi.org/10.1371/journal.pmed.1002603

Sullivan-Marx, E., & McCauley, L. (2017). Climate change, global health, and nursing scholarship. *Journal of Nursing Scholarship, 49*(6), 593-595. https://doi.org/10.1111/jnu.12342

Synnes, A., Luu, T. M., Moddemann, D., Church, P., Lee, D., Vincer, M., Ballantyne, M., Majnemer, A., Creighton, D., Yang, J., Sauve, R., Saigal, S., Shah, P., Lee, S. K., & Canadian Neonatal Network and the Canadian Neonatal Follow-Up Network. (2017). Determinants of developmental outcomes in a very preterm canadian cohort. *Archives of Disease in Childhood. Fetal and Neonatal Edition, 102*(3), F235-F234. https://doi.org/10.1136/archdischild-2016-311228

Synnes, Anne R., MDCM, FRCPC, MHSc, Anson, Shelagh, MD, FRCPC, Arkesteijn, A., MD, Butt, A., MSc, Grunau, R. E., PhD, Rogers, Marilyn, BSR, PT/OT, & Whitfield, Michael F., MD, FRCPC. (2010). School entry age outcomes for infants with birth weight ≤800 grams. *The Journal of Pediatrics, 157*(6), 989-994.e1. https://doi.org/10.1016/j.jpeds.2010.06.016

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., . . . Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine, 169*(7), 467-473. https://doi.org/10.7326/M18-0850

Vogel, J. P., Chawanpaiboon, S., Moller, A., Watananirun, K., Bonet, M., & Lumbiganon, P. (2018). The global epidemiology of preterm birth. *Clinical Obstetrics & Gynaecology, 52*, 3-12. https://doi.org/10.1016/j.bpobgyn.2018.04.003

Wang, J., Tong, S., Williams, G., & Pan, X. (2019). Exposure to heat wave during pregnancy and adverse birth outcomes: An exploration of susceptible windows. *Epidemiology (Cambridge, Mass.), 30 Suppl 1*, S115-S121. https://doi.org/10.1097/EDE.0000000000000995

Wang, Y., Li, Q., Guo, Y., Zhou, H., Wang, Q., Shen, H., Zhang, Y., Yan, D., Li, S., Chen, G., Zhou, S., He, Y., Yang, Y., Peng, Z., Wang, H., & Ma, X. (2020). Ambient temperature and the risk of preterm birth: A national birth cohort study in the mainland china. *Environment International, 142*, 105851. https://doi.org/10.1016/j.envint.2020.105851

Woo, Y., Ouh, Y. T., Ahn, K. H., Cho, G. J., Hong, S. C., Oh, M. J., & Kim, H. J. (2016). Seasonal Pattern of Preterm Births in Korea for 2000-2012. *Journal of Korean medical science, 31*(11), 1797–1801. https://doi.org/10.3346/jkms.2016.31.11.1797

Zhang, Y., Yu, C., & Wang, L. (2017). Temperature exposure during pregnancy and birth outcomes: An updated systematic review of epidemiological evidence. *Environmental Pollution (1987), 225*, 700-712. https://doi.org/10.1016/j.envpol.2017.02.066

Zheng, X., Zhang, W., Lu, C., Norbäck, D., & Deng, Q. (2018). An epidemiological assessment of the effect of ambient temperature on the incidence of preterm births: Identifying windows of susceptibility during pregnancy. *Journal of Thermal Biology, 74*, 201-207. https://doi.org/10.1016/j.jtherbio.2018.04.001

Zhong, Q., Lu, C., Zhang, W., Zheng, X., & Deng, Q. (2018). Preterm birth and ambient temperature: Strong association during night-time and warm seasons. *Journal of Thermal Biology, 78*, 381-390. https://doi.org/10.1016/j.jtherbio.2018.11.002