

# Systematic review on adverse birth outcomes of climate change

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**Background:** Climate change and global warming have significant effects on human health. This systematic review presents the effects of the climate changes on pregnancy outcomes. **Materials and Methods:** The search process was conducted in electronic databases including ISI Web of Knowledge, PubMed, Scopus, and Google Scholar using key words of “environmental temperature” “pregnancy” “low birth weight (LBW)” “pregnancy outcome,” “climate change,” “preterm birth (PTB),” and a combination of them. We did not consider any time limitation; English-language papers were included. The related papers were selected in three phases. After quality assessment, two reviewers extracted the data while the third reviewer checked their extracted data. Finally, 15 related articles were selected and included in the current study. **Results:** Approximately all studies have reported a significant relationship between exposure variable and intended outcomes including eclampsia, preeclampsia, cataract, LBW, PTB, hypertension, sex ratio and length of pregnancy. According to conducted studies, decrease in birth weight is more possible in cold months. Increase in temperature was followed by increase in PTB rate. According to most of the studies, eclampsia and preeclampsia were more prevalent in cold and humid seasons. Two spectrums of heat extent, different seasons of the year, sunlight intensity and season of fertilization were associated with higher rates of PTB, hypertension, eclampsia, preeclampsia, and cataract. **Conclusion:** Climate change has unfavorable effects on eclampsia, preeclampsia, PTB, and cataract. The findings of this review confirm the crucial importance of the adverse health effects of climate change especially in the perinatal period.

**Key words:** Climate change, infant, newborn, perinatal period, pregnancy, systematic review

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## INTRODUCTION

Global warming is one of the emerging concerns for the 21<sup>st</sup> century and is increasing in such a way that environmental temperature has been risen about 0/5-1°C since the mid-21<sup>st</sup>-century.<sup>[1]</sup> Strong scientific documents suggest that climate and weather changes are quickly rising. Human activities especially fossil fuels burning is one the important resources of global warming.<sup>[2]</sup> Children and infants are vulnerable people who are most at risk of climate changes related effects because of physical and physiological condition and lack of recognition maturation.<sup>[3]</sup> Environmental hazards quickly change and increase in result of the increase in climate change and harm to younger children and infants more than others.<sup>[4]</sup> Preterm birth (PTB) and low birth weight (LBW) are two important problems that may lead to mortality and other birth diseases and can affect significantly on other problems and diseases in future life of child.<sup>[5]</sup> Although hazards of climate changes for human health are known<sup>[6]</sup> but extent and amount of these hazards and its consequences especially on

pregnancy are not yet recognized. Given the importance of the effects of climate change on pregnancy outcomes, and in turn the lifelong effects of adverse pregnancy outcomes; the present study has considered the effects of climate changes on pregnancy outcomes including LBW and PTB using a systematic review.

## MATERIALS AND METHODS

### Search strategy

The search process was conducted in electronic databases including papers published until June 2014 in ISI Web of knowledge, PubMed, Scopus, and Google Scholar using key words of “environmental temperature,” “pregnancy,” “LBW,” “pregnancy outcome,” “climate change,” “PTB,” and a combination of them. To extract related articles in PubMed, medical subject heading was used. We considered cross-sectional, case-control, and longitudinal studies. Editorials, commentaries, and letter to editor papers were not included. The search was refined to the English language; we did not consider any time limitation. For any additional pertinent studies, the reference list of all relevant papers was screened as well.

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Titles and abstracts of papers were screened, and relevant papers were selected. Duplicates were removed. Then, full texts of relevant papers were read, and findings were rescreened. Two independent (PP and MK) reviewers screened titles and abstracts of papers identified by the literature searches for their potential relevance or assessed the full text for inclusion in the review. In the case of disagreement, and the discrepancy was resolved in consultation with a third arbitrating investigator (RK).

### Data extraction and abstraction

Two reviewers abstracted the data independently. The required information that was extracted from all eligible papers was as follows: Data on first author's last name, year of publication and country of the study population, the study name, study design characteristics, study population, type of study, aim and finding of studies.

Articles were excluded after reviewing their abstracts, and finally 15 articles<sup>[7-20]</sup> were included.

## RESULTS

Effects of climate change on pregnancy outcomes were considered. Figure 1 presents the study flowchart. Table 1 shows the data extracted from articles included in this review. Different studies were conducted around the world including Asia, Europe, and America; most of them were from America and Europe. The studies were performed according to different methods and principles. Effects of the temperature, different seasons of fertilization time, season of

childbirth, humidity and month of childbirth were assessed in these studies. Many diverse measurable outcomes were considered, e.g., eclampsia, preeclampsia, cataract, LBW, PTB, hypertension, sex ratio and length of pregnancy. Approximately all studies have reported a significant relationship between exposure variable and intended outcome. According to conducted studies, decrease in birth weight is more possible in cold months and winter. Increase in temperature was followed by increase in PTB rate. PTB was higher in exposure of the January to February months compared to March to October months.

Studies had presented different results about eclampsia and preeclampsia; however, according to most of the studies, they were more prevalent in cold and humid seasons. Some studies have reported higher risk in winter and some in summer. About the effect of month and season of fertilization on eclampsia and preeclampsia, it was shown that fertilization in the summer might increase the risk of these two conditions compared to fertilization in fall and winter.

## DISCUSSION

This systematic review assessed the relationship of climate change to some pregnancy outcomes. Different studies have measured effects of these changes on eclampsia, preeclampsia, cataract, LBW, PTB, hypertension, sex ratio, and length of pregnancy. In general, review of studies suggested harmful effects of the climate and temperature changes on human health. It must be noted that two temperature spectrums either cold or hot influenced health. In some studies, cold weather and in other hot weather were associated with health outcomes. About cataract, the hot weather and 5° increase in the temperature were associated with a cataract occurrence. In the study of Catalano *et al.*, cold weather was associated with an increase in the sex ratio and life duration of male sex in 1<sup>st</sup> year. Cold weather might produce these effects through different mechanisms including direct thermal effects, nutritional shortage and higher exposure to internal contaminants. Dadvand *et al.* studied hot weather or thermal stress and pregnancy length, they found that exposure to thermal stress was associated with 5 days decrease in the average pregnancy age. Secretion of oxytocin and heat-shock proteins in results of heat stress is increased; it is recognized as one of the factors related to PTB.<sup>[21-23]</sup> One of the other possible reasons of this consequence related to thermal exposure might be because of dehydration.<sup>[24]</sup>

Exposure to cold weather and birth in winter and fall that is, cold seasons, is reported to be associated with LBW and very LBW. PTB is found to be associated with two spectrums of weather extent (cold and hot). Exposure to cold weather, cold storm and high heat has been related to PTB. Increase in hydrosols,

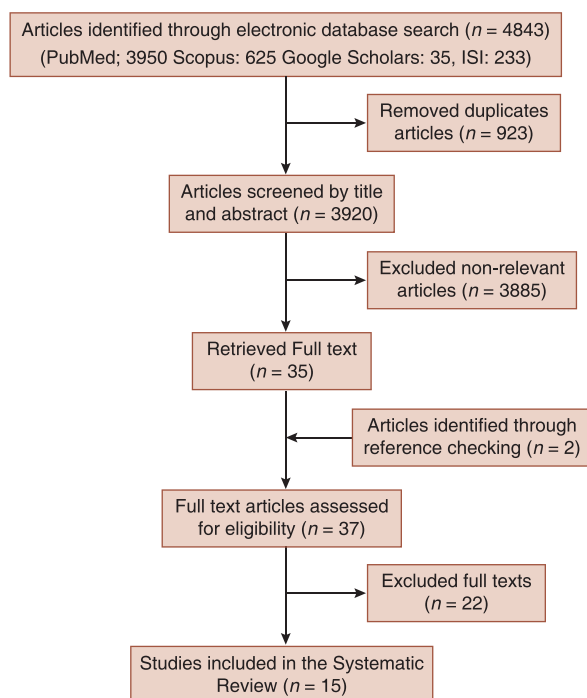


Figure 1: Flowchart of selecting primary studies for the systematic review

**Table 1: Summary of studies on the effects of climate change on birth outcomes**

Author, year	Title	Location	Population studied	Aim	Findings
Van Zutphen et al. 2012 <sup>[3]</sup>	A population-based case-control study of extreme summer temperature and birth defects	New York, USA	The source population was all live births to residents of upstate New York (New York State, excluding New York City) from 1992 through 2006	To determine whether pregnancies are potentially vulnerable to the weather extremes anticipated with climate change, we evaluated the relationship between extreme summer temperature and the occurrence of birth defects.	Among 6422 cases and 59,328 controls that shared at least 1-week of the critical period in summer, a 5° increase in mean daily minimum UAT was significantly associated with congenital cataracts (adjusted OR= 1.51; 95% CI: 1.14, 1.99). Congenital cataracts were significantly associated with all ambient temperature indicators as well: heatwave, number of heat waves, and number of days above the 90 <sup>th</sup> percentile. Inconsistent associations with a subset of temperature indicators were observed for renal agenesis/hypoplasia (positive) and anophthalmia/microphthalmia and gastroschisis (negative). It found positive and consistent associations between multiple heat indicators during the relevant developmental window and congenital cataracts
Catalano et al. 2008 <sup>[7]</sup>	Ambient temperature predicts sex ratios and male longevity	Scandinavia	It studied the annual cohorts born in Denmark, Finland, Norway, and Sweden started between 1878 and 1914	The theory that natural selection has conserved mechanisms by which women subjected to environmental stressors abort frail male fetuses implies that climate change may affect sex ratio at birth and male longevity	Using time series methods, it found that cold ambient temperatures during gestation predict lower secondary sex ratios and longer life span of males in annual birth cohorts composed of Danes, Finns, Norwegians, and Swedes born between 1878 (earliest year with complete life tables) and 1914 (last birth cohort for which male life span can be estimated). It concluded that the ambient temperature affects the characteristics of human populations by influencing who survives gestation
Dadvand et al. 2011 <sup>[9]</sup>	Climate extremes and the length of gestation	Barcelona, Spain	This study was based on a cohort of births that occurred in a major university hospital in Barcelona during 2001-2005	It investigated the impact of maternal short-term exposure to extreme ambient heat on the length of pregnancy	Mean temperature varies positively with the sex ratio but inversely with male cohort life span at age 1-year. Low temperatures, therefore, may cull males <i>in utero</i> and leave a more robust cohort compared with males born in years with warmer mean temperature
Hartig and Catalano 2013 <sup>[10]</sup>	Cold summer weather, constrained restoration, and VLBW in Sweden	Sweden	It obtained the data from the Swedish Medical Birth Registry, aggregated by month to avoid problems with small numbers and attendant concerns about anonymity	It tested the hypothesis that, in Sweden, the odds VLBW; o1500 g varies inversely with mean monthly temperature for the summer months. We applied time-series modeling	It found elevated odds of VLBW among male infants for relatively cold June and August temperatures
Aneire Eshar Khan 2011 <sup>[30]</sup>	Drinking water salinity and maternal health in Bangladesh	Bangladesh	Swedish women delivered an average of 8240 live infants each month over the 456 test months. Of these, an average of 44 infants per month weighed <1500 g	Method stonationally aggregated data on singleton births during the 456 months from January, 1973, through December, 2010	Taking the antilog of the estimated coefficients suggests that a colder than expected June yielded a 13.6% increase in the odds of a very low weight male infant. A colder than expected August yielded a 5.4% increase in VLBW frequency
			Water salinity data (1998-2000) in Bangladesh, were obtained. Information on drinking water sources, 24-h urine samples, and blood pressure was obtained from 343 pregnant women during the dry season (October 2009 through March 2010). The hospital-based prevalence of hypertension in pregnancy was determined for 969 pregnant women (July 2008 through March 2010)	It estimated the salt intake from drinking water sources and examined environmental factors that may explain a seasonal excess of hypertension in pregnancy	Average estimated sodium intakes from drinking water ranged from 5 to 16 g/day in the dry season, compared with 0.6-1.2 g/day in the rainy season. Average daily sodium excretion in urine was 3.4 g/day (range, 0.4-7.7 g/day). Women who drank shallow tube-well water were more likely to have urine sodium >100 mmol/day than women who drank rainwater (OR=2.05; 95% CI: 1.11-3.80). The annual hospital prevalence of hypertension in pregnancy was higher in the dry season (OR=12.2%; 95% CI: 9.5-14.8) than in the rainy season (OR=5.1%; 95% CI: 2.91-7.26)

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Author, year	Title	Location	Population studied	Aim	Findings
Basu et al. 2010 <sup>[12]</sup>	High ambient temperature and the risk of preterm delivery	California, USA	60,000 births spanning 16 counties in California that occurred from 1999 to 2006 between May and September	It studied the association of heat and humidity, as measured by apparent temperature, and preterm delivery	High ambient temperature was significantly associated with PTB for all mothers, regardless of maternal racial/ethnic group, maternal age, maternal education, or sex of the infant. An 8.6% increase (95% CI: 6.0, 11.3) in preterm delivery was associated with a 10_F (5.6_C) increase in weekly average (lag06) apparent temperature. These associations were independent of air pollutants. In the analysis of preterm delivery by gestational week, the strongest impacts were observed for PTBs from 34 to 36 gestational weeks (13.5%, 95% CI: 10.2, 16.9). For earlier PTBs, however, the association was significantly Negative (-5.2%, 95% CI: -9.9, -0.4). When the data were limited to only full-term births, a relatively small but significant association (1.8%, 95% CI: 0.8, 2.7) was found for the same-day lag of mean daily apparent temperature. No association was found for full-term births when weekly apparent temperature was considered (0.0%, 95% CI: -0.9, 0.9). A significantly negative association was found for both gestational weeks 37 and 38.
Auger et al. 2011 <sup>[14]</sup>	PTB during an extreme weather event in Quebec, Canada	Canada	Singleton live births for three periods (1993-1997, 1998, 1999-2003) were obtained (n=855,320)	To clarify the relationship between PTB and extreme weather events	Associations for 1998 relative to other periods were evaluated. Short-term (January to February) and long-term (March to October) exposure periods were examined. The proportion PTB for 1998 January to February births in the triangle (8.7%) was high compared with 1998 March to October births (6.0%) and with the corresponding proportions for 1993-1997 (6.2%) and 1999-2003 (6.9%). Covariate-adjusted odds of PTB for January to February 1998 were 27% higher for the Triangle relative to metropolitan Montréal, though precision was low. Furthermore, adjusted odds were 28% higher for 1998 relative to 1999-2003, despite increasing rates of PTB over time. Odds were not elevated over a long-term exposure period.
Algert et al. 2010 <sup>[16]</sup>	Seasonal variation in pregnancy hypertension is correlated with sunlight intensity	Australia	Data were obtained for 424,732 singleton pregnancies Conceived from 2001 through 2005 in Australia. We analyzed monthly rates of pregnancy hypertension and preeclampsia in relation To monthly solar radiation	To examine seasonality of pregnancy hypertension rates, and whether they related to sunlight levels around conception	Pregnancy hypertension rates, by month of conception, were lowest in autumn (7.3%) and highest in spring (8.9%). Higher sunlight intensity before delivery, but not around conception, was associated with decreased pregnancy hypertension. Increased sunlight around conception correlated with decreased rates of early onset preeclampsia. The correlation between sunlight after conception and pregnancy hypertension was opposite to that hypothesized; however, sunlight levels before delivery did correlate with lower hypertension rates.
Subramaniam 2007 <sup>[19]</sup>	Seasonal variation in the incidence of preeclampsia and eclampsia in tropical climatic conditions	India	It retrospectively analyzed data from a large maternity center in Mumbai, India over a period of 36 months from March 1993 to February 1996, recording the incidence of preeclampsia and eclampsia	It aimed to study the correlation between the incidence of eclampsia and preeclampsia with various weather parameters in the tropical coastal city of Mumbai	Over a 36-month period, a total of 29,562 deliveries were recorded, of which 1238 patients developed preeclampsia (4.18%) and 34 developed eclampsia (0.11%). The incidence of eclampsia was significantly higher in the cool and rainy seasons.
Magnu and Eskild 2001 <sup>[20]</sup>	Seasonal variation in the occurrence of preeclampsia	Norway	All 1,869,388 deliveries in Norway in the years 1967-1998 were included in this study. The relative risks of preeclampsia by month of delivery were estimated as OR using the month with the lowest risk as the reference category	To obtain evidence for seasonal variability in preeclampsia using the assumption that environmental factors may have a role in the causal mechanisms	Mothers of children born in August had the lowest risk of preeclampsia, and the risk was highest in the winter months (for December adjusted OR=1.26, 95% CI: 1.20-1.31). This pattern was independent of parity, maternal age, year and place of living.

(Continued)



**Table 1: (Continued)**

Author, year Title	Location	Population studied	Aim	Findings
Phillips et al. 2004 <sup>[16]</sup>	USA	142 primiparous women with singleton pregnancies with preeclampsia were compared with 7762 controls	It evaluated whether the preeclampsia occurred seasonally and whether the timing of conception or delivery is more strongly associated with risk	Preeclampsia occurred in 1.8% of singleton primiparous gestations (142/7904). It found no significant association of month of delivery with the risk of preeclampsia. A significant association was documented between the of month of conception with risk of preeclampsia. Conception during the summer months had the highest risk (incidence 2.3%; OR= 1.7; 95% confidence limits: 1.06, 2.75) compared with spring (incidence 1.4%). Fall (1.7%) and winter (1.6%) conceptions were associated with intermediate rates of preeclampsia
Wolf and Armstrong 2012 <sup>[8]</sup>	Germany	300,000 births from two German states were studied	The aim of this study was to examine a potential seasonal rhythm of adverse pregnancy outcome in two German populations and possible future health impacts of temperature	It documented a weak evidence for an association between season of conception, season of birth or ambient outdoor temperature and LBW or PTB
Kristen Wellington 2011 <sup>[15]</sup>	Texas, USA	Retrospective analysis of hospital discharge records of 312,207 women who delivered in Texas in 2007 was performed. The outcome was preeclampsia or eclampsia	A cross-sectional study was conducted to determine the association of the season of delivery and the prevalence of preeclampsia/eclampsia	Seasonal variation was minimal with the lowest prevalence detected in the fall (3.89%) and a peak of 4.1% in the winter. The highest monthly prevalence was found in January (4.4%). After adjusting for maternal age, race, and other potential confounders, women who were admitted in the fall for delivery were 6% less likely than women who were admitted in the winter to have preeclampsia: adjusted OR=0.94, 95% CI: 0.89-0.99, P=0.02
Tam et al. 2008 <sup>[17]</sup>	Texas	It studied the singleton primipara women who delivered between 1995 and 2002. The odds of developing preeclampsia across months and the association between the preeclampsic rates based on the months of conception and the mean monthly heat index were documented	This study aimed to determine the relationship between ambient temperatures adjusted for humidity at conception and the occurrence of preeclampsia	A total of 245 (1.6%) women were diagnosed preeclampsia and eclampsia during the study period. There was a significant association between the seasons of conception and rate of preeclampsia. Conceptions during summer had a higher risk of preeclampsia than those during autumn (2.3 vs. 1.6%, OR=1.7, 95% CI: 1.2-2.5)
Jensen and Sørensen 2013 <sup>[11]</sup>	60 countries worldwide	The impact of temperatures, altitude, nutrition, age at motherhood and other potential causes for BW variation were evaluated in more than 60 countries worldwide	This study aimed to assess the potential determinants of BW	This study identified a model explaining 2/3 of the global variation in BW. This model suggests that BW will decrease by 0.44-1.05% per each °C increase in temperature under projected climate change

BW = Birth weight; VLBW = Very low birth weight; UAT = Universal apparent temperature; PTB = Preterm birth; OR = Odds ratio; CI = Confidence interval

viscosity, blood vessel and blood cholesterol have been stated as possible factors.<sup>[25,26]</sup> This relationship has been more frequent in mothers with younger age, black race, and Asian background. It is documented that hypertension, eclampsia, and preeclampsia were more frequent in cold weather; cold seasons with more wind and rain. In addition, fertilization in the summer might increase the chance of developing preeclampsia. In addition, increased sunlight intensity has been associated with a decrease in blood pressure. Factors like the effects of Vitamin D, increase in temperature, ultraviolet light, and seasonal infections are mentioned as possible factors.<sup>[27-29]</sup> Increasing number of studies related to weather and temperature changes highlights the importance of these changes in human health especially on mothers and infants.

Above review included some limitations such as lack of homogeneity between studies, different methodologies, different sample size and variations in the studied populations.

Diverse studies have been conducted about effects of different aspects of climate change including the temperature, season, rain and wind on human health and their results have documented different adverse health effects of climate change on human health. The findings of the current review confirm the crucial importance of the harmful effects of climate changes in the perinatal period.

## AUTHORS' CONTRIBUTION

All authors contributed in the study design, conducting the systematic review, and drafting the manuscript. All authors approved the final version for submission and take the responsibility for the manuscript content.

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