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Temperature exposure during pregnancy and birth outcomes: An updated systematic review of epidemiological evidence☆

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ABSTRACT

Seasonal patterns of birth outcomes have been observed worldwide, and there was increasing evidence that ambient temperature played as a trigger of adverse birth outcomes, such as preterm birth (PTB), low birth weight (LBW), and stillbirth. To systematically review updated epidemiological evidence about the relationship between temperature exposure during pregnancy and PTB, LBW, and stillbirth, we searched for related studies published in English from electronic databases and references of identified papers. We only included original articles that directly reported the effects of prenatal temperature exposure on birth outcomes. The characteristics and main findings of included studies were examined. A total of 36 epidemiological studies were finally included in this review. Most of these studies focused on PTB and LBW, while less attention has been paid to stillbirth that was relatively rare in the occurrence. Several designs including ecological (e.g., descriptive and time-series) and retrospective cohort studies (e.g., case-crossover and time-to-event) were applied to assess temperature effects on birth outcomes. Temperature metrics and exposure windows varied greatly in these investigations. Exposure to high temperature was generally found to be associated with PTB, LBW, and stillbirth, while several studies also reported the adverse impact of low temperature on birth outcomes of PTB and LBW. Despite no conclusive causality demonstrated, the current evidence for adverse effect on birth outcomes was stronger for heat than for cold. In summary, the evidence linking birth outcomes with ambient temperature was still very limited. Consequently, more related studies are needed worldwide and should be conducted in diversified climate zones, so as to further ascertain the association between temperature and birth outcomes. Future studies should focus on more sophisticated study designs, more accurate estimation of temperature exposure during pregnancy, and more efficient methods to find out the exposure windows, as well as cold-related effects on birth outcomes.

1. Introduction

Maternal and child health is one of the most important global public health problems concerning social development and human generation, which has been listed as a notable part of United Nations Millennium Development Goals (GBD 2015 SDG Collaborators, 2016). As a widely existing health threat, adverse birth outcomes can produce great disease burden on fetal health status at birth and future growth and development (Saigal and Doyle, 2009). Preterm birth (PTB), for instance, defined as the birth of an infant prior to 37 weeks' gestation, has been linked with a variety of adverse health outcomes, such as acute morbidity or mortality, and long-term defects or problems in growth, behavior and cognition (Saigal and Doyle, 2009). The estimated number of PTB infants was approximately 15 million in 2010 worldwide, which accounted for 11% of all live births (Blencowe et al., 2012). As for another common adverse birth outcome, low birth weight (LBW) refers to births less than 2500 g and also contributes a lot to infant mortality and childhood morbidity (McCormick, 1985), as well as individual health throughout the life course (Grace et al., 2015). It was reported by WHO that in 2004–2005, 15.5% (more than 20 million) of all infants were born with LBW worldwide, and 95.6% of the total LBW babies occurred in developing countries (WHO, 2004).

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Adverse birth outcomes are generally considered induced by the complex effects of multiple risk factors including genetic, behavioral, socio-economic and environmental factors (Strand et al., 2011). As one of the most important environmental stressors, climate change has been widely regarded as the greatest global threat for human health in the 21st century because of its broad direct or indirect impacts on the vast majority of the world's population (Anthony et al., 2009; Huang et al., 2013). Numerous previous epidemiologic studies (Gasparrini et al., 2015; Gronlund et al., 2014; Ma et al., 2015; Ye et al., 2012) including some national and multi-country investigations have linked a series of health outcomes (e.g., morbidity and mortality) with temperature extremes (i.e., cold and heat). Among the potential subpopulations vulnerable to weather changes, pregnant women have received less attention (He et al., 2016) compared with the elderly (Bunker et al., 2016).

In very recent years, there was increasing evidence showing that ambient temperature exposure during pregnancy could also trigger the occurrence of PTB, LBW, and stillbirth in some climate zones (Basu et al., 2016; He et al., 2016; Ngo and Horton, 2016; Schifano et al., 2016). In the context of great burden due to adverse birth outcomes and global climate change, it is of great necessity and urgency to clarify the relationship between fetal birth outcomes and prenatal temperature exposure. In this paper, we therefore conducted an updated systematic review of epidemiological evidence that linked ambient temperature with birth outcomes. Based on the findings and limitations of identified studies, we also made several recommendations about the research direction for future investigations in this field.

2. Materials and methods

2.1. Search strategies and article selection

We conducted a systematic search of current epidemiologic literature published in peer-reviewed English journal. We restricted the online publication time up to November 2016, and searched electronic databases including PubMed, Medline, Scopus, Web of Science and Google Scholar. The following keywords or combinations of them were used in the search strategies: “preterm birth”, “gestational age”, “birth weight”, “stillbirth”, “birth outcomes”, “climate change”, “temperature”, and “weather”.

In this review, we only included original articles that directly assessed the correlation or relationship between prenatal temperature exposure (e.g., ambient temperature, heat waves, or cold spells) and one or more birth outcomes (i.e., preterm birth, LBW, and stillbirth). To include all of the related studies as comprehensively as possible, we also examined the references of the articles identified. Of the 1264 articles identified in the initial database search, 1183 articles were excluded after screening the titles, 38 were further excluded after reviewing the abstracts and 7 were excluded after assessing the full texts. Consequently, a total of 36 papers were finally included in this review (Fig. 1).

2.2. Study quality assessment

We conducted the quality assessment of included studies in line with Critical Appraisal Skills Programme (CASP) guidelines for evaluating quantitative studies (CASP, 2003, 2013), which were pioneered by the National Health Service in the UK and have been widely applied to determine the study quality of quantitative publications in many research fields (e.g., nursing, medical, and midwifery) (Carolan-Olah and Frankowska, 2014). CASP guidelines used in this review focused on three broad issues (i.e., Section A, B, and C) when appraising included studies, and investigated a number of aspects of the research publications, which included clear focus on the addressed issue, acceptable recruitment strategy, appropriate study method, measurement bias, identification and treatment of confounding factors, believable results, and consistency with other available evidence (see Box 1). Since question 6 (Q.6) related to the follow up of included subjects, and was inappropriate for studies linking birth outcomes with ambient

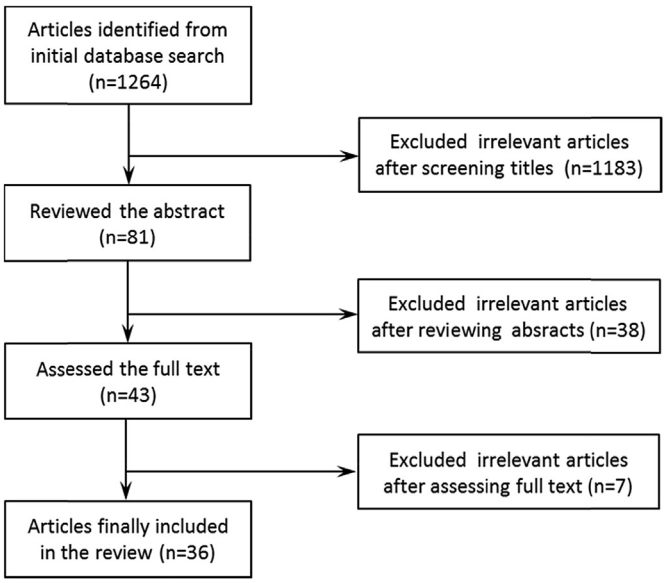

Fig. 1. Flow chart of article select process.

Box 1
Items of CASP guidelines used for quality assessment of included studies in this review.

CASP guidelines	Score 0/1
(Section A) Are the results of the study valid?	
Q1. Did the study address a clearly focused issue?	0/1 (No/Yes)
Q2. Was the cohort recruited in an acceptable way?	0/1 (No/Yes)
Q3. Was the exposure accurately measured to minimise bias? (prenatal temperature exposure)	0/1 (No/Yes)
Q4. Was the outcome accurately measured to minimise bias? (fetal birth outcomes)	0/1 (No/Yes)
Q5. a. Have the authors identified all important confounding factors?	0/1 (No/Yes)
b. Have they taken account of the confounding factors in the design and/or analysis?	0/1 (No/Yes)
Q6. a. Was the follow up of subjects complete enough?	NA
b. Was the follow up of subjects long enough?	NA
(Section B) What are the results?	
Q7. What are the results of this study? (Are the results demonstrated clearly?)	0/1 (No/Yes)
Q8. How precise are the results?	0/1 (No/Yes)
Q9. Do you believe the results? (Are the results believable?)	0/1 (No/Yes)
(Section C) Will the results help locally?	
Q10. Can the results be applied to the local population?	0/1 (No/Yes)
Q11. Do the results of this study fit with other available evidence?	0/1 (No/Yes)
Q12. What are the implications of this study for practice? (Are there any implications for practice?)	0/1 (No/Yes)