CEOG Clinical and Experimental Obstetrics & Gynecology

Effect of relative humidity on preeclampsia

G.J. Cho[1*], K.H. Ahn[1*], L.Y. Kim[2], S.Y. Hwang[3], S.C. Hong[1], M.J. Oh[1], H.J. Kim[1]

[1] Department of Obstetrics and Gynecology, Korea University College of Medicine, Seoul
[2] The Health Insurance Review and Assessment Service of Korea, Seoul
[3] Department of Biostatistics, College of Medicine, Korea University, Seoul (South Korea)

Summary

Purpose of investigation: The authors aimed to determine the relationship between meteorological variables and hypertension in pregnancy by using data from a national weather database. *Materials and Methods:* For this population-based observational study, the database of the Korea National Health Insurance (KNHI) Claims of the Health Insurance Review and Assessment Service (HIRA) and Korea Meteorological Administration was used. The 48,275 women with preeclampsia among 2,495,383 women who gave birth were included. Monthly meteorological factors and preeclampsia prevalence for five years were statistically analyzed. *Results:* Among temperature, relative humidity, sunlight duration, and rainfall, only relative humidity had a significant inverse correlation with the preeclampsia prevalence ($p < 0.001$). The other meteorological factors were not associated with preeclampsia. *Conclusion:* Relative humidity may be a significant factor for of the development of preeclampsia. Further monitoring of weather parameters during the entire pregnancy period may be the best method for verifying the present results in the development of preeclampsia.

Key words: Relative humidity; Temperature; Sunlight; Rain; Preeclampsia.

Introduction

Pregnancy-related hypertension is a major cause of maternal and fetal morbidity and mortality worldwide. Seasonal variations have been definitively associated with cardiovascular mortality [1]; likewise, clinicians have suspected that seasonal variations influence the development of preeclampsia. The results of prior studies have been inconsistent, however, and cross-study comparisons have been difficult owing to differences in the investigated weather zones and variables such as temperature, humidity, and sunlight intensity. Some studies showed that in the Northern Hemisphere, preeclampsia at delivery was more prevalent in women who became pregnant in summer (higher temperatures) and less prevalent in women who became pregnant in winter (lower temperatures). According to other studies, higher sunlight intensity around the delivery time lowered preeclampsia prevalence [2-5]. The results regarding the effect of humidity have been even more varied across geographical regions, early pregnancy or delivery seasons, and weather zones [2, 4, 6-9]. To reliably determine the effect of seasonality on hypertension in pregnancy, investigating global weather variables in conjunction with large amounts of population-based data would be reasonable. Therefore, the authors aimed to determine the relationship between meteorological data and hypertension in pregnancy by using a national weather database.

Materials and Methods

Data on preeclampsia from 2006 to 2010 were collected from the Korea National Health Insurance (KNHI; Claims Database of the Health Insurance Review and Assessment Service [HIRA]). In South Korea, 97% of the population is obligated to enroll in the KNHI program. Health insurance policies require healthcare providers to allow HIRA to review the medical costs incurred. The remaining 3% of the population is under the Medical Aid Program. Thus, the HIRA database contains information on all claims for approximately 50 million Koreans, and nearly all disease-related information for the population can be obtained from this centralized database. Exceptions include procedures that are not covered by insurance, such as cosmetic surgery. Many epidemiological analyses that utilized this database have been published. In accordance with the Act on the Protection of Personal Information Maintained by Public Agencies, HIRA conceals individual identities when preparing claims data. Studies using these data are therefore exempt from any institutional review board review.

Diagnostic procedure codes of the *International Classification of Diseases, 10th Revision* (*ICD-10*) were used to identify all women who gave birth during the study period. The diagnostic criteria for preeclampsia used in Korea are blood pressure ≥ 140/90 mm Hg after 20 weeks' gestation combined with proteinuria (≥ 0.3 g/24 hours or ≥ +1 in a urine dipstick; *ICD-10* code O14).

Data on monthly averages of meteorological parameters, including temperature (°C), sunshine duration (hours), relative humidity (%), and rainfall (mm), were collected from the Korea Meteorological Administration. The authors analyzed the monthly prevalence rates of preeclampsia development and investigated potential associations between the prevalence rate of preeclampsia development and various meteorological factors by using an

*G.J. Cho and K.H. Ahn are both first authors.

Revised manuscript accepted for publication November 16, 2015

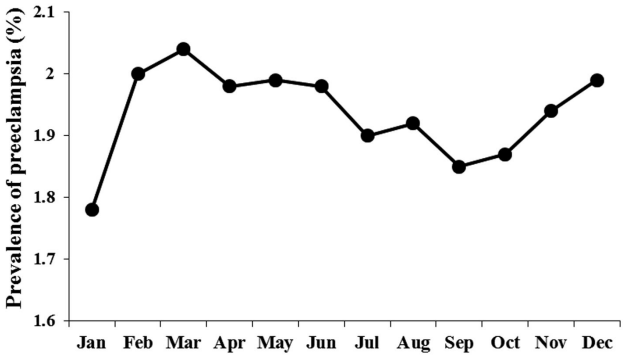

Figure 1. — Monthly variation in preeclampsia prevalence.

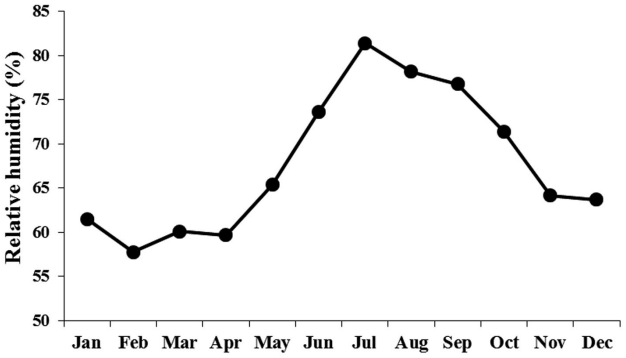

Figure 2. — Monthly variation in relative humidity.

Table 1. — *Multivariate regression analysis of the association between preeclampsia prevalence and meteorological factors.*

Variable	Estimate	Standard error	*t* value	*p*
Average temperature (°C)	0.489	0.39	1.25	0.215
Sunlight duration (hours)	-0.012	0.078	-0.22	0.83
Relative humidity (%)	-1.33	0.47	-2.85	<0.001
Rainfall (mm)	0.033	0.018	1.85	0.069

autoregressive error model. Relative humidity was calculated with the following equation [10]:

$$\Phi = e_W/e^*_W \times 100\%,$$

where Φ is the relative humidity, e_W is the partial pressure of water vapor (H_2O), and e^*_W is the equilibrium pressure of water vapor.

A two-sided p value < 0.05 was considered statistically significant. Statistical analyses were performed by using the SPSS version 12.0 software.

Results

Over the 60-month period, 2,495,383 deliveries were recorded and 48,275 women (1.93%) developed preeclampsia. When the preeclampsia prevalence was analyzed across time, the mean monthly preeclampsia prevalence over five years peaked in March and exhibited a minimum in September (Figure 1). The low preeclampsia prevalence in January was considered an outlier. The mean temperature was highest in August (25.46°C) and lowest in January (−0.34°C). The mean intensity of sunlight was strongest in May (214.86 hours) and weakest in December (150.02 hours). The mean relative humidity was highest in July (81.2%) and lowest in April (60.02%; Figure 2). The mean rainfall was highest in July (368.98 mm) and lowest in January (26.84 mm). Multivariate regression analyses using the autoregressive error model showed that only relative humidity was significantly and inversely associated with the prevalence of preeclampsia ($p < 0.001$), whereas temperature, intensity of sunlight, and rainfall showed no such associations (Table 1).

Discussion

The reported relationships between seasonal weather variations and hypertension in pregnancy have been inconsistent among the geographical regions studied to date. In this study, seasonal variations in preeclampsia in a temperate zone were associated with relative humidity. Korea experiences four distinct seasons, with winter, with its low relative humidity, having the highest preeclampsia prevalence. As this is the largest nationwide population-based study yet conducted using meteorological data, the authors believe that it provides a definitive answer to the controversy surrounding the seasonal variations in the occurrence of preeclampsia. In particular, given that other studies did not include all the four variables used in this study in their statistical evaluations, the authors could reasonably assume that the association they detected between relative humidity and preeclampsia prevalence remains significant.

The present results on the association between lower relative humidity and higher incidence of preeclampsia are consistent with those of some previous studies. A study conducted in Kuwait included 28,262 deliveries and found that pregnancy-induced hypertension at delivery time was significantly associated with relative humidity [4]. Another study also reported that lower humidity at the approximate time of conception was associated with a higher incidence of preeclampsia [2]. The consistent importance of relative humidity in both prior studies as in the present study is interesting.

The insignificant relationship between temperature and preeclampsia in the present study is supported by another earlier study. In 1995, Magann *et al.* showed that changes in temperature at constant humidity did not affect the inci-

dence of preeclampsia [11].

Some mechanisms to explain how humidity affects blood pressure can be proposed. Humans reduce their body temperature via perspiration, and high ambient humidity can disturb this process [3]. Miyamoto *et al.* reported that recovery of core temperature after cooling was delayed in women with preeclampsia [12]. This phenomenon was explained by a possible disturbance of the vasodilation process and the properties of microcirculation in preeclampsia. Therefore, it is understandable that relatively low humidity can induce cardiovascular disturbance with subsequent hypertension.

Considering that relative humidity is inversely related to sunlight exposure and temperature for a given dew point [13], temperature, sunlight intensity, and rainfall may be closely correlated with relative humidity in terms of controlling blood pressure, even though the associations with these parameters were not statistically significant in the present study. In particular, autonomic neurotransmitters, hormones, and infections related to temperature variations, as well as vitamin D level, immunomodulation, and level of melatonin related to light intensity changes, could theoretically be involved in the pathophysiological mechanism of preeclampsia [14-22].

One factor that should be considered when interpreting the present data is the time of data collection. The present data describe the prevalence of preeclampsia at delivery. The possibility of differential effects of weather factors on hypertension according to gestational age has been suggested [5]. Sunlight exposure during the conception month was associated with increased rates of pregnancy-related hypertension, whereas sunlight exposure at delivery reduced pregnancy-related hypertension. Given that the pathophysiological mechanism of preeclampsia may include poor placentation in early pregnancy and considering the potential seasonal differences between conception and delivery months, generalizing the present authors' conclusion to all women with preeclampsia would be difficult. Hereafter, a study using meteorological data at the time of conception is needed for a more-complete evaluation.

The present conclusions may have clinical implications. In particular, physicians could use the information this study provides on the potential effect of humidity on hypertension in pregnancy for counseling and management of pregnant women at high risk of preeclampsia.

Nonetheless, the present study had some limitations. First, the patients' demographic data were not considered. Access to individual information was limited because the data were collected from national databases (KNHI Claims Database of the HIRA Service and the database of the Korea Meteorological Administration) with identifying information removed. Analyses accounting for confounding variables such as patient age, parity, body mass index, gestational age at delivery, history of smoking and alcohol consumption, and multifetal pregnancy would result in more reliable conclusions regarding the relationship between humidity and preeclampsia. Second, although the present study analyzed what the authors considered as the four most important weather parameters (temperature, humidity, rainfall, and sunlight intensity), other meteorological factors such as latitude, altitude, aspect, sea proximity, ocean currents, air pressure, and wind may also be important effectors of blood pressure.

Future studies monitoring these specified global weather parameters during the entire pregnancy period may be the best approach to verify the present results and fully reveal the role of meteorological factors, including humidity, in the development of preeclampsia.

Conclusion

Based on the present data, unlike other meteorological factors, relative humidity may be a significant factor of the development of preeclampsia.

References

[1] Scragg R., Jackson R., Holdaway I.M., Lim T., Beaglehole R.: "Myocardial infarction is inversely associated with plasma 25-hydroxyvitamin D3 levels: a community-based study". *Int. J. Epidemiol*., 1990, *19*, 559.

[2] Nasiri R., Ahmadi Shadmehri A., Khajeh Ghiassi P., Sarafraz Yazdi M., Mazloum Farsi Baf M.: "Association of meteorological factors and seasonality with preeclampsia: a 5-year study in northeast of Iran". *Clin. Exp. Hypertens*., 2014, *36*, 586.

[3] Tam W.H., Sahota D.S., Lau T.K., Li C.Y., Fung T.Y.: "Seasonal variation in pre-eclamptic rate and its association with the ambient temperature and humidity in early pregnancy". *Gynecol. Obstet. Invest*., 2008, *66*, 22.

[4] Makhseed M., Musini V.M., Ahmed M.A., Monem R.A.: "Influence of seasonal variation on pregnancy-induced hypertension and/or preeclampsia". *Aust. N. Z. J. Obstet. Gynaecol.,* 1999, *39*, 196.

[5] Algert C.S., Roberts C.L., Shand A.W., Morris J.M., Ford J.B.: "Seasonal variation in pregnancy hypertension is correlated with sunlight intensity". *Am. J. Obstet. Gynecol*., 2010, *203*, 215.e1.

[6] Tan G.W., Salmon Y.M.: "Meteorological factors and pre-eclampsia". *Singapore Med. J*., 1988, *29*, 133.

[7] Wacker J., Schulz M., Frühauf J., Chiwora F.M., Solomayer E., Bastert G.: "Seasonal change in the incidence of preeclampsia in Zimbabwe". *Acta Obstet. Gynecol. Scand*., 1998, *77*, 712.

[8] Obed S.A., Wilson J.B., Elkins T.E.: "Eclampsia: 134 consecutive cases". *Int. J. Gynaecol. Obstet*. 1994, *45*, 97.

[9] Ros H.S., Cnattingius S., Lipworth L.: "Comparison of risk factors for preeclampsia and gestational hypertension in a population-based cohort study". *Am. J. Epidemiol.,* 1998, *147*, 1062.

[10] Perry R.H., Green D.W., Maloney J.O.: *Perry's chemical engineers' handbook*, 7th ed. New York: McGraw-Hill, 1997.

[11] Magann E.F., Perry K.G., Jr., Morrison J.C., Martin J.N., Jr.: "Climatic factors and preeclampsia-related hypertensive disorders of pregnancy". *Am. J. Obstet. Gynecol*., 1995, *172*, 204.

[12] Miyamoto S., Shimokawa H., Touno A., Kurokawa T., Nakano H.: "Characteristics of changes in blood circulation induced by cold stimulation in pre-eclamptic women". *Int. J. Gynaecol. Obstet*., 1988, *27*, 159.

[13] University Corporation for Atmospheric Research: "Temperature and relative humidity relationships", 2008. Available at: http://stream2.cma.gov.cn/pub/comet/FireWeather/S290Unit5TemperatureandRelativeHumidityRelationships/comet/fire/s290/unit5/print.htm#z4_0

[14] Khatun S., Kanayama N., Belayet H.M., Masui M., Sugimura M., Kobayashi T., *et al.*: "Induction of preeclampsia like phenomena by stimulation of sympathetic nerve with cold and fasting stress". *Eur. J. Obstet. Gynecol. Reprod. Biol*., 1999, *86*, 89.

[15] Arechavaleta-Velasco F., Koi H., Strauss J.F. III, Parry S.: "Viral infection of the trophoblast: time to take a serious look at its role in abnormal implantation and placentation?" *J. Reprod. Immunol*., 2002, *55*, 113.

[16] Haugen M., Brantsaeter A.L., Trogstad L., Alexander J., Roth C., Magnus P., et al.: "Vitamin D supplementation and reduced risk of preeclampsia in nulliparous women". *Epidemiology*, 2009, *20*, 720.

[17] Marya R.K., Rathee S., Manrow M.: "Effect of calcium and vitamin D supplementation on toxaemia of pregnancy". *Gynecol. Obstet. Invest*., 1987, *24*, 38.

[18] TePoel M.R., Saftlas A.F., Wallis A.B.: "Association of seasonality with hypertension in pregnancy: a systematic review". *J. Reprod. Immunol*., 2011, *89*, 140.

[19] Robinson C.J., Alanis M.C., Wagner C.L., Hollis B.W., Johnson D.D.: "Plasma 25-hydroxyvitamin D levels in early-onset severe preeclampsia". *Am. J. Obstet. Gynecol*., 2010, *203*, 366.e1.

[20] Hossain N., Khanani R., Hussain-Kanani F., Shah T., Arif S., Pal L.: "High prevalence of vitamin D deficiency in Pakistani mothers and their newborns". *Int. J. Gynaecol. Obstet.,* 2011, *112*, 229.

[21] Ringrose J.S., PausJenssen A.M., Wilson M., Blanco L., Ward H., Wilson T.W.: "Vitamin D and hypertension in pregnancy". *Clin. Invest. Med*., 2011, *34*, E147.

[22] Wilson M.L., Desmond D.H., Goodwin T.M., Miller D.A., Ingles SA.: "Maternal and fetal variants in the TGF-beta3 gene and risk of pregnancy-induced hypertension in a predominantly Latino population". *Am. J. Obstet. Gynecol*., 2009, *201*, 295.e1.

Corresponding Author:
M.J. OH, M.D., Ph.D.
Department of Obstetrics and Gynecology
Korea University Guro Hospital
Korea University College of Medicine
148 Gurodong-ro, Guro-gu
Seoul 152-703 (South Korea)
e-mail: mjohmd@korea.ac.kr