Clinical and Experimental Obstetrics & Gynecology

Clin. Exp. Obstet. Gynecol. **2022**; 49(6): 127
https://doi.org/10.31083/j.ceog4906127

Original Research

Influence of Atmospheric Conditions on Labor Onset: A Single-Center Retrospective Cross-Sectional Study in Japan

Satoshi Hosoya[1], Tetsuro Tsujimoto[2,3,*], Hajime Oishi[1], Miyuki Sadatsuki[1]

[1]Department of Obstetrics and Gynecology, National Center for Global Health and Medicine, 162-8655 Tokyo, Japan
[2]Department of Diabetes, Endocrinology and Metabolism, National Center for Global Health and Medicine, 162-8655 Tokyo, Japan
[3]Department of Diabetes and Endocrinology, Toranomon Hospital Kajigaya, 213-8587 Kanagawa, Japan
*Correspondence: ttsujimoto@hosp.ncgm.go.jp (Tetsuro Tsujimoto)

Academic Editor: Michael H. Dahan
Submitted: 23 January 2022 Revised: 17 March 2022 Accepted: 21 March 2022 Published: 2 June 2022

Abstract

Background: Although the mechanism underlying labor onset is controversial, there is an empirical finding that bad weather influences it. Previous reports have focused mainly on the relationship between the timing of deliveries and the weather conditions; fewer reports have focused on the timing of labor onset. Thus, we investigated the relationship for identifying atmospheric factors contributing to labor onset. **Methods**: We conducted a Japanese single-center retrospective cross-sectional study for identifying atmospheric factors contributing to labor onset over 8 years. We gathered daily atmospheric data in Tokyo from the official homepage of the Japan Meteorological Agency; mean barometric pressure, total solar irradiation, mean vapor pressure, and difference between the warmest and coldest temperatures. The percentage of days on which 1 or more laboring woman was hospitalized and the number of laboring women hospitalized per day were evaluated between low and middle/high groups for each atmospheric condition. **Results**: In total 1178 eligible women, the percentage of days significantly increased on days of low total solar irradiation (low group: 38% vs middle/high group: 31%; $p < 0.001$). The number of laboring women also significantly increased in such conditions (low group: 0.46 vs middle/high group: 0.38; $p < 0.001$). There were no significant differences in others. **Conclusions**: On days of low sunshine, pregnant women are more likely to start laboring. Further investigations will be needed to clarify the relationship between solar irradiation and labor onset.

Keywords: weather condition; labor onset; solar irradiation; epidemiology; Japan

1. Introduction

For thousands of years, people have believed that natural phenomena such as the lunar cycle, weather conditions, or seasonality influence childbirth. As such, there have been many papers discussing the relationship between natural phenomena, seasonality, and obstetric problems [1–3]. For example, "The Christmas effect" is one of the most famous rumors relating to the association between seasonality and obstetrics, which suggests that the rate of conception is highest around the December holidays [4]. In addition, there is an empirical finding known to experienced obstetricians and midwives that bad weather conditions induce labor onset. In fact, previous studies have evaluated the relationship between deliveries and environmental factors, such as barometric pressure, temperature, humidity, wind, and, recently, particulate matter 2.5 [1,5–7]. Some of these studies showed that temperature and barometric pressure might influence deliveries [5,6]. Furthermore, because of the recent global attention to climate change, the number of studies focusing on the relationship between climate change and pregnancy has increased [8,9]. Thus, the relationship between pregnancy and various atmospheric factors should be further investigated.

In the same way, there is considerable information available online relating to the empirical finding that weather conditions influence not only the timing of deliveries but also the timing of labor onset. However, while most previous reports have focused mainly on the relationship between the timing of deliveries and natural phenomena, the timing of labor onset has not been assessed extensively. Although the mechanism and key factors of labor onset are yet to be clarified, the understanding and expectation of labor onset will enable obstetricians and obstetric staff to provide appropriate management for pregnant women. Therefore, the relationship between labor onset and atmospheric conditions is worth investigating. The present study aimed to assess the relationship between weather conditions and labor onset and consider the underlying mechanisms.

2. Methods

2.1 Study Population and Data Collection

This analysis was planned as a single-center retrospective cross-sectional study. We used data of birth records of the National Center for Global Health and Medicine between January 1, 2011 and December 31, 2018. In our institution, there are almost 400–500 births per year. Inclusion criteria were women hospitalized for labor onset at 37–41 weeks' gestation. We basically did not include women hospitalized for other major reasons of hospitalization of term pregnant women, such as premature rupture of membrane, hypertensive disorders of pregnancy, planned caesarean section or induced labor in this trial. Labor onset was defined as the presence of regular, painful uterine contractions, and some measure of cervical dilatation [10]. According to the definition of the Japan Society of Obstetrics and Gynecology, we considered labor onset to have begun when cyclic labor pains were experienced six times per hour or once every 10 minutes. Exclusion criteria were women with labor onset at preterm or post-term, women living outside Tokyo, multiple pregnancy, and incomplete obstetrical data in the database. Sample size was thought to be from 1000 to 2000 cases, referring to previous single-center studies [5,6].

2.2 Measures and Main Outcomes

We collected daily atmospheric data from the Japan Meteorological Agency, which was free to access on their official homepage. The observation point was Tokyo (35° latitude and 140° longitude). We selected four atmospheric variables for analysis: mean barometric pressure, total solar irradiation, mean vapor pressure, and temperature difference between the warmest and coldest temperatures in a day. Each atmospheric variable was divided equally in three groups: low, middle, and high groups, and the participants were assigned to three groups according to the value of the particular atmospheric variable at the time of labor onset.

We calculated the percentage of days on which at least one laboring woman was hospitalized (described as "the percentage of days") during the entire study period. Because 2 or more laboring women were hospitalized on some days, we also evaluated the number of women hospitalized for labor onset per day (described as "the number of laboring women"). The percentage of days was defined as the total number of days on which at least one laboring woman was hospitalized (numerator) divided by the total number of days during the entire period of each group separately (denominator) and multiplied by 100, in the low and middle/high groups. Similarly, the number of laboring women was defined as the total number of pregnant women hospitalized for labor onset (numerator) divided by the total days during the entire period of each group (denominator). We compared these outcomes between the low and middle/high groups for each atmospheric condition (as described in Statistical Analysis). If we could determine the significant differences in some atmospheric variables with regard to the percentage of days and the number of laboring women, we would plan further investigation on the assessment of seasonal effects in these rates in every season—spring (March–May), summer (June–August), autumn (September–November), and winter (December–February)—in the same way.

We assessed the relationship between the percentage of days and low or middle/high conditions for each atmospheric variable. As an example, to calculate the percentage of days when mean barometric pressure was low, we divided the total number of days on which at least one laboring woman was hospitalized (300 days) by the total days during the entire period in the low barometric pressure group (900 days) and multiplied it by 100, to give the percentage of 33%. The same analysis was carried out for the number of laboring women. If, in the low barometric pressure group, we had 400 pregnant women who were hospitalized for labor onset and total 900 days during the entire period, the number of laboring women was 0.44.

2.3 Statistical Analysis

Continuous data are presented as means ± standard deviation, categorical data are presented as percent. Each atmospheric variable is presented as mean and interquartile range (IQR). Continuous variables were analyzed using t-test and categorical variables were analyzed using χ^2 test. We considered p-values of $<$0.05 to be statistically significant. Statistical analyses were conducted using Stata software (version 14.1, Stata Corp., College Station, Texas, USA).

3. Results

During the 8-year study period, we recruited a total of 1321 pregnant women who were hospitalized for labor onset. The flow diagram of study enrollment is presented in Fig. 1. Finally, 1178 women were enrolled for analysis (Fig. 1). No women were hospitalized for labor onset at post-term because elective labor induction is routinely offered before 42 weeks' gestation at our institute. There were no cases of multiple pregnancies hospitalized for labor onset at 37–41 weeks' gestation because elective Cesarean section is routinely performed around 37 weeks of gestation. Participant characteristics are detailed in Table 1.

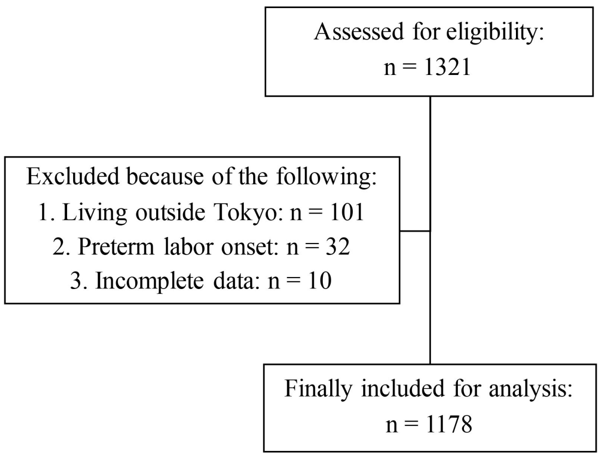

Fig. 1. Flow diagram of study enrollment. A total of 1178 women were eligible and analyzed.

Table 1. Participant characteristics.

Total number of women: N = 1178	
Age, years	33.0 ± 4.7
Gestational week at hospitalization, weeks	39.1 ± 0.9
Parity	
Primigravida	657 (55.8%)
Multigravida	521 (44.2%)
Mode of delivery	
Vaginal delivery	1120 (95%)
Cesarean section	58 (5.0%)
Main obstetric complications	
Hypertensive disorders of pregnancy	59 (5.0%)
Gestational diabetes mellitus	33 (2.8%)

Data are presented as mean ± standard deviation or number (percent).

The relationship between atmospheric variables and the percentage of days is shown in Table 2. There was no significant difference in the percentage of days in relation to barometric pressure, vapor pressure, or temperature difference. However, we observed a significant difference in the percentage of days when participants were divided according to total solar irradiation, with low total solar irradiation associated with a significantly higher rate than the middle/high group.

Moreover, the relationship between atmospheric variables and the number of laboring women is shown in Table 3. The number of laboring women was significantly higher for the low total solar irradiation group than for the middle/high group. In contrast, barometric pressure, vapor pressure, and temperature difference did not significantly affect the number of laboring women.

In addition, the backgrounds of women in the low and middle/high groups of total solar irradiation are shown in Table 4. There is no difference in the woman characteristics in both groups.

The outcomes of total solar irradiation were significantly different; therefore, we further investigated the seasonal effects on the percentage of days and the number of laboring women, the results of which are listed in **Supplementary Tables 1a,b,2a,b**. The levels of total solar irradiation (MJ/m^2) in each season were 19.0 ± 7.8 (Spring, March–May), 17.9 ± 7.6 (Summer, June–August), 11.3 ± 5.4 (Autumn, September–November), and 11.0 ± 4.1 (Winter, December–February; shown as mean ± standard deviation). At first, we assessed these outcomes in the warmer seasons (from spring to summer) and the colder seasons (from autumn to winter). The percentage of days was significantly increased for the women who received low amounts of total irradiation (**Supplementary Table 1a**) in both warmer and colder seasons. In addition, in the warmer seasons, the number of laboring women who received low amounts of total irradiation also significantly increased (**Supplementary Table 1b**). Finally, we performed the same analysis to assess the percentage of days and women within each season (**Supplementary Table 2a,b**). In the spring and summer seasons, these outcomes were significantly increased women who received low amounts of total solar irradiation. In the autumn and winter seasons, these outcomes intended to be higher than those of women who received middle/high amounts of total solar irradiation.

4. Discussion

The effect of nature on our health has been of interest to humans for centuries. Studies have revealed that some natural phenomena affect specific aspects of human health; for example, heart failure is exacerbated by cold temperatures [11] and the rate of depression increases with decreased sunlight during the winter season [12]. In the field of obstetrics, it is believed that natural phenomena such as the lunar cycle and weather conditions influence the occurrence of childbirth, although its validity is controversial. Previous reports have mainly focused on the relationship between natural phenomena, the timing of childbirth and incidences of preterm birth, premature membrane rupture, and other obstetric complications [1–3]. Morton-Pradhan *et al.* [1] reported that there is no significant correlation between birth rate and the stage of the lunar cycle or atmospheric conditions (including barometric pressure, dew point, and temperature) in the state of Arizona. Arliss *et al.* [2] also concluded that there is no obvious relationship between lunar cycle and birth rate in the state of North California from a study including more than 100,000 births from official birth certificate data of the USA. Muresan *et al.* [6] reported the incidence of weekly premature births significantly increased with average temperature and temperature variation, through retrospective analysis of almost 1800 eligible women from the obstetrical database of their own hospital. However, there are few studies on the relationship between natural phenomena and labor onset, compared with studies about birth rate or the incidence of premature birth. Akutagawa *et al.* [5] conducted a retrospective analysis of the relationship between barometric pressure and obstetric events including labor onset, premature membrane rupture, and childbirth at their hospital, including almost 2000 participants, which led them to conclude that, although the number of spontaneous deliveries increased on days when barometric pressure was low, there was no significant relationship between barometric pressure and the number of pregnant women hospitalized for labor onset. Polansky *et al.* [13] also reported no relationship between labor onset and barometric pressure. Based on our result and previous reports, labor onset does not seem to be affected by barometric pressure. Further, low mean vapor pressure and low temperature difference between the warmest and coldest temperatures in a day did not have significant effects on labor onset. No previous report has focused on the effects of these factors on labor onset; therefore, further studies are needed for making a conclusion.

Table 2. Relationship between atmospheric variables and the percentage of days.

	Mean value [IQR]	The percentage of days (%)*	p-value
Mean barometric pressure, hPa			
Low	1002.7 [1000.8–1005.5]	34 (327/975)	0.63
Middle/High	1013.9 [1010.1–1017.1]	33 (636/1947)	
Total solar irradiation, MJ/m^2			
Low	5.7 [3.5–8.0]	38 (368/974)	$<$0.001
Middle/High	17.5 [12.7–21.8]	31 (595/1948)	
Mean vapor pressure, hPa			
Low	5.1 [3.8–6.3]	32 (308/971)	0.31
Middle/High	18.8 [12.7–25.0]	34 (655/1951)	
Temperature difference between the warmest and coldest temperatures in a day, °C			
Low	4.8 [3.9–5.9]	35 (343/981)	0.10
Middle/High	9.1 [7.6–10.2]	32 (620/1941)	

During the 8 years of the study period (from January 1, 2011 to December 31, 2018, total 2922 days), we recruited 1178 pregnant women. Participants were equally divided into three groups for each atmospheric variable: low, middle, and high group.

Data are presented as mean [interquartile range] or percentage (number/number). The p-values were calculated by comparison of the low group with the middle and high groups (combined) using χ^2 test.

*The percentage of days was defined as the number of days for which a pregnant woman or more was hospitalized due to labor onset divided by the total number of days during the entire period of each group separately and multiplied by 100, in the low and middle/high groups.

IQR, interquartile range; hPa, hectopascal; MJ/m^2, mega joules per square meter.

Table 3. Relationship between atmospheric variables and the number of laboring women.

	Mean value [IQR]	The number of laboring women*	p-value
Mean barometric pressure, hPa			
Low	1002.7 [1000.8–1005.5]	0.41 (400/975)	0.67
Middle/High	1013.9 [1010.1–1017.1]	0.40 (778/1947)	
Total solar irradiation, MJ/m^2			
Low	5.7 [3.5–8.0]	0.46 (447/974)	$<$0.001
Middle/High	17.5 [12.7–21.8]	0.38 (731/1948)	
Mean vapor pressure, hPa			
Low	5.1 [3.8–6.3]	0.38 (372/971)	0.23
Middle/High	18.8 [12.7–25.0]	0.41 (806/1951)	
Temperature difference between the warmest and coldest temperatures in a day, °C			
Low	4.8 [3.9–5.9]	0.42 (413/981)	0.28
Middle/High	9.1 [7.6–10.2]	0.39 (765/1941)	

During the 8 years of the study period (from January 1, 2011 to December 31, 2018, total 2922 days), we recruited 1178 pregnant women. Continuous data are presented as mean [interquartile range]. The p-values were calculated by comparison of the low group with the middle and high groups (combined) using unpaired t-test.

*The number of laboring women was defined as the total number of pregnant women hospitalized for labor onset divided by the total number of days of the above atmospheric variables in the low and middle/high groups.

IQR: interquartile range, hPa: hectopascal, MJ/m^2: mega joules per square meter.

Moreover, the relationship between labor onset and total solar irradiation has not been reported. However, our result showed that total solar irradiation had a significant effect on labor onset; days of low solar irradiation were associated with increased numbers of women hospitalized due to labor onset. Based on our results, we speculated some hypothesis to answer why low amounts total solar irradiation affects labor onset in the consideration to several hormones regulated by sunlight. First, recent reports have stated the relationship between hormones associated with vitamin D and perinatal outcomes [12,14,15]. Vitamin D is one of the famous hormones synthesized by sunlight ex-

Table 4. Participant characteristics in the low and middle/high groups of total solar irradiation.

	Low group	Middle/high group	p-value
	N = 447	N = 731	
Age, years	33.1 ± 4.7	32.9 ± 4.8	0.49
Gestational week at hospitalization, weeks	39.2 ± 0.9	39.1 ± 1.0	0.28
Parity			
Primigravida	259 (57.9)	398 (54.4)	0.24
Multigravida	188 (42.1)	333 (45.6)	
Mode of delivery			
Vaginal delivery	425 (95.1)	695 (95.1)	0.99
Cesarean section	22 (4.9)	36 (4.9)	
Main obstetric complications			
Hypertensive disorders of pregnancy	20 (4.5)	35 (4.8)	0.51
Gestational diabetes mellitus	22 (4.9)	36 (4.9)	0.86

Data are presented as mean ± standard deviation or number (percent).

The p-values were calculated by comparison of the low group with the middle and high groups (combined) using unpaired t-test for continuous variables and χ^2 test for categorical variables.

posure. Shibata *et al*. [14] found that threatened premature delivery within 3rd trimester was associated with lower serum 25-hydroxyvitamin D (25-(OH)D) levels in Japanese population, which indicates that longitudinal 25-(OH)D deficiency, associated with lower sun exposure, may start the mechanism of uterine contraction. Because our report showed that the short-term effect of low amounts of total solar irradiation in a single day was related to labor onset, further information may be interesting for the obstetrical effects of daily change of serum levels of vitamin D or calcium. The other hormone that may play a role is melatonin, which is a regulator of circadian rhythm and a scavenger of free radicals. As it is well-known that the production of melatonin is regulated by solar irradiation and has the diurnal variation, Sharkey *et al*. [16] insisted that the pigment was involved in the induction of parturition, similar to oxytocin. They also referred that melatonin could induce contraction of the human myometrium and might bind strongly to myometrial membranes during laboring. One report demonstrated that exposure of the lamp light to eyes to suppress melatonin secretion caused impaired uterine contraction [17]. Trap *et al*. [18] reported that labor onset often starts at night, when the melatonin level is generally high, and they mentioned the possibility of the positive effects of circadian rhythm on labor onset. According to these reports, we can hypothesize that higher levels of melatonin on days with low solar irradiation may induce cyclic uterine contraction thus initiating labor onset. Recently, it has been revealed that decreased progesterone and increased inflammation cytokines such as prostaglandin are important for labor onset [19]. Therefore, it may be interesting in investigating the association between these sunlight-related hormones, progesterone and inflammation cytokines.

Furthermore, we assessed the seasonal effect of total solar irradiation on labor onset. In each season, particularly spring and summer, the percentage of days and the number of laboring women receiving low amounts of solar irradiation were higher than those receiving middle/high amounts of solar irradiation. According to the results, the assumption is that labor onset tends to be more affected by the days of low solar irradiation during the hot seasons with higher solar irradiation on average than during the cold seasons with lower solar irradiation on average. In view of the relationship between sunlight and seasonality and obstetrical outcomes, Algert *et al*. [20] reported that morbidity from pregnancy hypertension is lower in spring and summer; during these seasons, higher the levels of sunlight, lower the monthly hypertension rates. According to their report and our result, we think that the effect of seasonality, in terms of total solar irradiation, on pregnant women is worth investigating. To the best of our knowledge, this is the first epidemiological report to investigate the relationship between total solar irradiation and labor onset. Because the above discussions are just assumptions, further investigations are warranted to confirm the results through which low total solar irradiation can induce labor onset.

There are some limitations of this study which should be acknowledged. The first was our sample size; according to our database, only 1321 women were hospitalized for labor onset during the study period, although there are approximately 400–500 births annually in this hospital. The other main reasons for obstetric hospitalization included scheduled cesarean section, induction of labor, rupture of membranes, threatened preterm birth, and maternal complications, such as hypertensive disorder of pregnancy and gestational diabetes mellitus; women hospitalized for these reasons were naturally ineligible for inclusion in this analysis. Moreover, we could not precisely assess whether the women excluded also experienced labor onset when hospitalized. Thus, this study was affected by sample size bias and selection bias. Previous single-center studies with almost 1000–2000 eligible participants, such as those of Akutagawa *et al*. [5] and Muresan *et al*. [6], have revealed obvious effects of weather conditions on the incidence of obstetrical problems. We believe that the influence of weather on inhabitants of a single area can be assessed more precisely in single-center studies than in large-area analyses, even if the study population is small. To obtain more reliable data and minimize sample size bias and selection bias, neighboring multicenter prospective analyses with larger numbers of participants are necessary. Second, we could not assess the precise time of labor onset because we defined that it as when the woman was admitted to hospital. However, this is unlikely to influence our results significantly because eligible women were limited to those residing in Tokyo who could visit the hospital within an hour or so. Third, we did not evaluate the effects of solar irradiation changes within a single day or between days compared with that of weekly solar irradiation with respect to labor onset. Fourth, because we did not assess the location and behavior of pregnant women when cyclic uterine contractions were felt, for example, staying or sleeping at home, or walking outside, and the duration of their outdoor activity, we cannot conclude that the relationship between labor onset and solar irradiation was a direct causal relationship. Fifth, according to our result, it would be worthwhile to investigate the relationship between preterm labor onset and each atmospheric condition. However, our database included only 32 women with preterm labor onset during the study period who were excluded from our primary analysis; our preliminary analysis revealed no statistical difference among the percentage of days, the number of laboring women and each atmospheric condition (**Supplementary Table 3a,b**). Since the preterm birth rate in Japan is low (5.6%) [21] and our primary interest is the relationship between labor onset and atmospheric conditions, solely with respect to pregnant women hospitalized for labor onset, the sample size of laboring women at preterm in this study was quite small. Therefore, this relationship requires further research with larger sample sizes. Finally, we used a univariable simplistic statistical approach in this study because we hypothesized that atmospheric factors were independent of general background characteristics, such as age and parity; thus, we did not evaluate obvious confounding factors. Researchers in further studies should investigate the effect of weather change on obvious factors related to labor onset, such as premature membrane rupture or cervical ripening.

5. Conclusions

There are a lot of unproved empirical findings relating to the obstetric area, and the precise mechanism of labor onset is still unclear. The present study demonstrates that pregnant women with hospitalized due to labor onset tend to be hospitalized in a day with low total solar irradiation. Weather changes may be an important aspect of research for the mechanism of labor onset.

Data Sharing Statement

The datasets analyzed in the present study are available from the corresponding author on reasonable request.

Author Contributions

SH, TT, HO and MS contributed to the study design and conception, material preparation, and data collection. Data analysis was performed by SH and TT. The first draft of this text, figures, and tables was written and created by SH, and TT, HO and MS commented on the first version of this manuscript. SH, TT, HO and MS approved the final manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

All subjects gave their informed consent for inclusion in this study by posting the optout at the outpatient office of our department. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of National Center for Global Health and Medicine (approval number: NCGM-G-003245-00).

Acknowledgment

The Authors would like to thank Enago (www.enago.jp) for the English language review.

Funding

This work was supported by the Grants-in-Aid for Research from the National Center for Global Health and Medicine [20A3002].

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.ceog4906127.

References

[1] [1] Morton-Pradhan S, Bay RC, Coonrod DV. Birth rate and its correlation with the lunar cycle and specific atmospheric conditions. American Journal of Obstetrics and Gynecology. 2005; 192: 1970–1973.

[2] Arliss JM, Kaplan EN, Galvin SL. The effect of the lunar cycle on frequency of births and birth complications. American Journal of Obstetrics and Gynecology. 2005; 192: 1462–1464.

[3] Yackerson N, Piura B, Sheiner E. The influence of meteorological factors on the emergence of preterm delivery and preterm premature rupture of membrane. Journal of Perinatology. 2008; 28: 707–711.

[4] Cesario SK. The “Christmas Effect” and other Biometeorologic Influences on Childbearing and the Health of Women. Journal of Obstetric, Gynecologic & Neonatal Nursing. 2002; 31: 526–535.

[5] Akutagawa O, Nishi H, Isaka K. Spontaneous delivery is related to barometric pressure. Archives of Gynecology and Obstetrics. 2007; 275: 249–254.
[6] Muresan D, Staicu A, Zaharie G, Marginean C, Rotar IC. The influence of seasonality and weather changes on premature birth incidence. Clujul Medical. 2017; 90: 273–278.
[7] Alman BL, Stingone JA, Yazdy M, Botto LD, Desrosiers TA, Pruitt S, *et al*. Associations between PM2.5 and risk of preterm birth among liveborn infants. Annals of Epidemiology. 2019; 39: 46–53.e2.
[8] Kuehn L, McCormick S. Heat Exposure and Maternal Health in the Face of Climate Change. International Journal of Environmental Research and Public Health. 2017; 14: 853.
[9] Rylander C, Øyvind Odland J, Manning Sandanger T. 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. 2013; 6: 19538.
[10] Hanley GE, Munro S, Greyson D, Gross MM, Hundley V, Spiby H, *et al*. Diagnosing onset of labor: a systematic review of definitions in the research literature. BMC Pregnancy and Childbirth. 2016; 16: 71.
[11] Qiu H, Tak-sun Yu I, Tse LA, Tian L, Wang X, Wong TW. Is Greater Temperature Change within a Day Associated with Increased Emergency Hospital Admissions for Heart Failure? Circulation: Heart Failure. 2013; 6: 930–935.
[12] Hoel DG, de Gruijl FR. Sun Exposure Public Health Directives. International Journal of Environmental Research and Public Health. 2018; 15: 2794.
[13] Polansky GH, Varner MW, O'Gorman T. Premature rupture of the membranes and barometric pressure changes. The Journal of Reproductive Medicine. 1985; 30: 189–191.
[14] Shibata M, Suzuki A, Sekiya T, Sekiguchi S, Asano S, Udagawa Y, *et al*. High prevalence of hypovitaminosis D in pregnant Japanese women with threatened premature delivery. Journal of Bone and Mineral Metabolism. 2011; 29: 615–620.
[15] Roth DE, Morris SK, Zlotkin S, Gernand AD, Ahmed T, Shanta SS, *et al*. Vitamin D Supplementation in Pregnancy and Lactation and Infant Growth. New England Journal of Medicine. 2018; 379: 535–546.
[16] Sharkey JT, Puttaramu R, Word RA, Olcese J. Melatonin Synergizes with Oxytocin to Enhance Contractility of Human Myometrial Smooth Muscle Cells. The Journal of Clinical Endocrinology & Metabolism. 2009; 94: 421–427.
[17] Olcese J, Lozier S, Paradise C. Melatonin and the Circadian Timing of Human Parturition. Reproductive Sciences. 2013; 20: 168–174.
[18] Trap R, Helm P, Lidegaard O, Helm E. Premature Rupture of the Fetal Membranes, the Phases of the Moon and Barometer Readings. Gynecologic and Obstetric Investigation. 1989; 28: 14–18.
[19] Shynlova O, Lee Y, Srikhajon K, Lye SJ. Physiologic Uterine Inflammation and Labor Onset. Reproductive Sciences. 2013; 20: 154–167.
[20] Algert CS, Roberts CL, Shand AW, Morris JM, Ford JB. Seasonal variation in pregnancy hypertension is correlated with sunlight intensity. American Journal of Obstetrics and Gynecology. 2010; 203: 215.e1–215.e5.
[21] Japanese Ministry of Health, Labour and Welfare. Vital Statistics of Japan. 2019. Available at: https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00450011&tstat=000001028897&cycle=7&year=20190&month=0&tclass1=000001053058&tclass2=000001053061&tclass3=000001053064&result_back=1&tclass4val=0 (Accessed: 16 March 2022).