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Atmospheric conditions, lunar phases, and childbirth: a multivariate analysis

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Abstract Our objective was to assess extrinsic influences upon childbirth. In a cohort of 1,826 days containing 17,417 childbirths among them 13,252 spontaneous labor admissions, we studied the influence of environment upon the high incidence of labor (defined by 75th percentile or higher), analyzed by logistic regression. The predictors of high labor admission included increases in outdoor temperature (odds ratio: 1.742, $P=0.045$, 95%CI: 1.011 to 3.001), and decreases in atmospheric pressure (odds ratio: 1.269, $P=0.029$, 95%CI: 1.055 to 1.483). In contrast, increases in tidal range were associated with a lower probability of high admission (odds ratio: 0.762, $P=0.030$, 95%CI: 0.515 to 0.999). Lunar phase was not a predictor of high labor admission ($P=0.339$). Using multivariate analysis, increases in temperature and decreases in atmospheric pressure predicted high labor admission, and increases of tidal range, as a measurement of the lunar gravitational force, predicted a lower probability of high admission.

Keywords Childbirth · Labor · Temperature · Atmospheric pressure · Tidal range · Lunar phases

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Introduction

In hospital delivery units, health professionals often report experiencing days on which labor admissions appear to escalate. Several researchers have identified the periodicity of human birth in daily, weekly or seasonal patterns (Anderka et al. 2000; Cesario 2002; Lerchl 2008; Mancuso et al 2004; Seron-Ferre et al. 1993). In addition, there is a persistent perception that the onset of labor is influenced by environmental facts. It is believed that lunar influence, more specifically full moon, may trigger an increased amount of labor cases (Ghiandoni et al. 1998). However, the scientific data concerning lunar influence upon labor admissions are controversial. Although climatic conditions, predominantly atmospheric pressure, have been reported to be factors that influence labor (Akutagawa et al. 2007; Driscoll 1995; Hirsch et al. 2010; King et al. 1997; Noller et al. 1996), there have been few studies using multivariate analysis with which to assess this association.

The purpose of the present study was to assess the variables of outdoor temperature, atmospheric pressure, humidity, precipitation, pollutants, lunar phases, and tidal range as potential triggers of labor onset.

Materials and methods

To investigate environmental influences upon the onset of labor, we selected consecutive labor admissions and births between January 1, 2003 and December 31, 2007.

Setting

The current study was carried out in the delivery unit of a university hospital, in São Paulo, Brazil (23°33′54″S, 46°44′26″W). Multidisciplinary assistance was provided to women from the Brazilian Public Health System (SUS), with normal- or medium-risk pregnancies. Brazilian cesarean rates in the public hospitals range from 20 to 40% and from 70 to 90% in private hospitals (Davis-Floyd 2007). Our institution is government-funded hospital, and our rates are 30.7% of cesarean section and 69.3% of vaginal delivery. We defined normal vaginal delivery as childbirth through the vagina, whether or not assisted, induced or conduced, contrasting with a delivery by cesarean section. Labor admission was defined when women were hospitalized by obstetrician in spontaneous onset of labor to childbirth.

We studied two periods. The first, between 2003 to 2007 (n=13,252 spontaneous labor admission), was used for distribution in periods of day; days of week and association with meteorological variables, pollutants and tidal range. The second period, between 1982 to 2007 (n=74,897 childbirth) was used for distribution in month of the year.

Parturient women

We included consecutive parturient women who were admitted in spontaneous labor diagnosis and full-term pregnancy (≥37 weeks of gestation). We excluded women with pregnancy below 37 weeks and without labor diagnosis as: prolonged pregnancy, diabetes, pre-eclampsia, prelabour rupture of the membranes, oligohydramnios, fetal growth restriction, known fetal anomaly, and programmed cesarean section.

Endpoint

In the current study, days were numbered according to: the number of admissions, mean outdoor temperature, mean atmospheric pressure, humidity, precipitation, pollutants, lunar phase and tidal range. The primary endpoint was an excessive number of labor admissions, defined by 9 or more admissions per day (>75th percentile: P75 group).

The obstetric outcomes (normal vaginal delivery or cesarean section), the newborn outcomes (gestational age) and others information were registered in our database.

All research data were collected by following institutions of University of Sao Paulo: University Hospital; Institute of Astronomy, Geophysics and Atmospheric Science; Oceanographic Institute; and by Sao Paulo state's Environmental Sanitation Technology Company (CETESB).

Atmospheric measurements

The atmospheric measurements were provided by a database of Institute of Astronomy, Geophysics and Atmospheric Science, which is located 19.6 km from our hospital.

Outdoor temperature was measured using an Assmann-type mercury thermometer (Fuess™) in °C. Atmospheric pressure was measured with a Kew-type mercury barometer (Fuess™), in hectopascal (hPa) units. The humidity was measured as a percentage using an Assmann psychrometer (Fuess™), and precipitation in millimeters was measured with a Hellmann-type rain gauge (Lambrecht™).

The pollutant measurements were provided by Sao Paulo state's Environmental Sanitation Technology Company (CETESB) where is located 6.4 km from our hospital.

The measure of particulate matter pollutants (PM_{10}) was measured in μg/m3 and carbon monoxide (CO) in parts-per-million (ppm).

Tidal range measurement

Tidal range measurements were provided by the Oceanographic Institute which is located at Santos City, at sea level, 81.8 km distant from our hospital which is at an altitude of 760 m. The tidal range was measured, in meters, using a floating tidal gauge (AOTT).

Ethical issues

The present study was approved by the Ethical Committee for Research of University Hospital, USP. The Ethical Committee allowed the researchers to access the women's data, while individual parturient data were kept confidential. However, the electronic database did not have all the women's records. The analyzed data were admission diagnosis, admission date and hour, childbirth date and hour, delivery method, and the newborn gestational age.

Statistical analysis

Continuous variables with Gaussian distribution were expressed by mean and standard deviation and assessed by Student's t test. Non-Gaussian variables were assessed by the Mann–Whitney test. Values of continuous variables were transformed to z scores (value minus mean/standard deviation). The z scores of atmospheric pressure, temperature, and tidal range for each day were subtracted from the previous day. Studied days were classified according to a drop in atmospheric pressure greater than a z score of 0.25,

an increase in temperature of a z score over 0.5, and an increase in tidal range with a z score above 0.5. Categorical variables were expressed by proportion, and compared between groups using a χ^2 or Fisher's exact test.

We used the expected proportion of one of four periods of a day (25.00%), one day of a week (14.28%) and one month of a year (8.33%) to compare with the proportions of our sample.

Variables that were associated with an increase in labor by univariate analysis (P value<0.10), or those of clinical interest, were selected for multivariate analysis with the logistic regression model (Hosmer and Lemeshow 1989), performed with SAS software (SAS Institute, Cary, NC, USA). Odds ratios with a 95% confidence interval were calculated. A two-tailed P value <0.05 was considered significant.

Results

The mean age of patients was 24.97 (SD=6.22) years old, the majority of patients (51.4%) had at least 9 years of education, 45.4% were nulliparous, 81,7% were admitted in labor, and 69.3% were normal vaginal delivery. The gestational age was 38.8 (SD=1.8) weeks, 92.6% of the pregnancies were at least 37 weeks of gestation, and 51.1% of the infants were male.

In the period between January 1, 2003 and December 31, 2007 (1,826 days), there were 17,417 childbirths. In full-term pregnancies, 13,252 were spontaneous labor admissions, while within these, 10,263 admissions were for normal vaginal delivery. The average number of daily spontaneous labor admissions was 7.25±2.86 patients.

In the study period, the average outdoor temperature was 19.37±3.28°C, atmospheric pressure was 926.2±3.52 hPa, humidity was 79.95±8.45%, and precipitation was 3.93± 10.37 mm. Pollution, measured as PM_{10}, was 43.25± 25.17 µg/m3, and the average CO level was 1.924±1.414 . The tidal range was 1.04±0.35 m. P75 admission days constituted 25% of the days (577).

Main findings

Among spontaneous labor admission, there was a peak (32%) between 0700 and 1300 hours (P<0.001). During the week, more spontaneous labor admission occurred on Mondays (15.2%; P=0.001) and Fridays (15.1%; P=0.004) in contrast with average rate on Saturdays and Sundays, respectively, as shown in Figs. 1 and 2.

Per annual period, all childbirths (from 1982 to 2007; n= 74,897) were distributed according to the month of the year. Peaks were evident in March (8.8%; P<0.001), April (8.5%; P=0.029), and May (9.1%; P<0.001), as shown in Fig. 3.

By multiple linear regression analysis, we only found an association of labor admission to maximum temperature (P= 0.029), with a correlation coefficient of 0.056.

Days were assigned to either the P75 group (high rate of admissions, >75th percentile) or the control group (<75th percentile). The average outdoor temperature was 19.6±3.2 and 19.3±3.3°C for P75 and control groups, respectively, with a mean difference of +0.291 (95% CI: −0.034 to +0.615).

Fig. 1 Distribution of labor admission according to period of the day
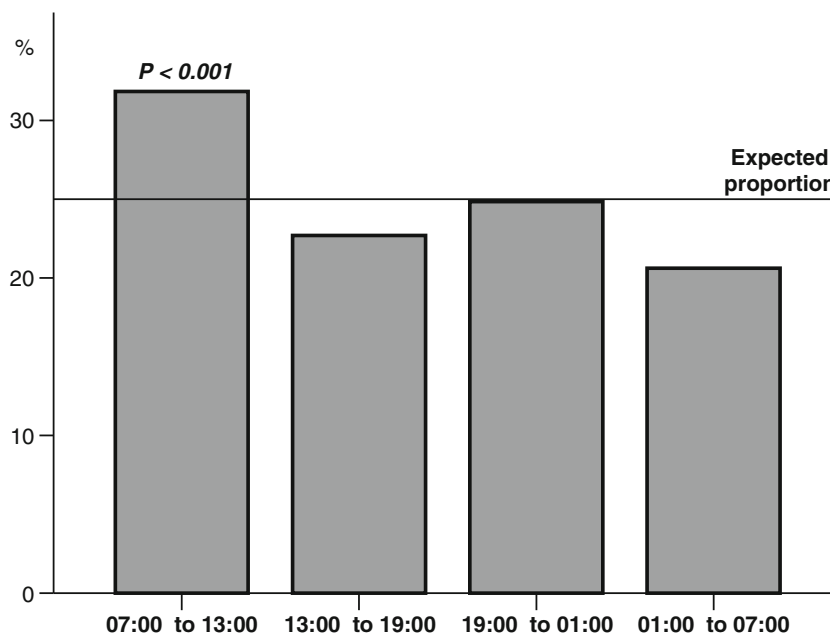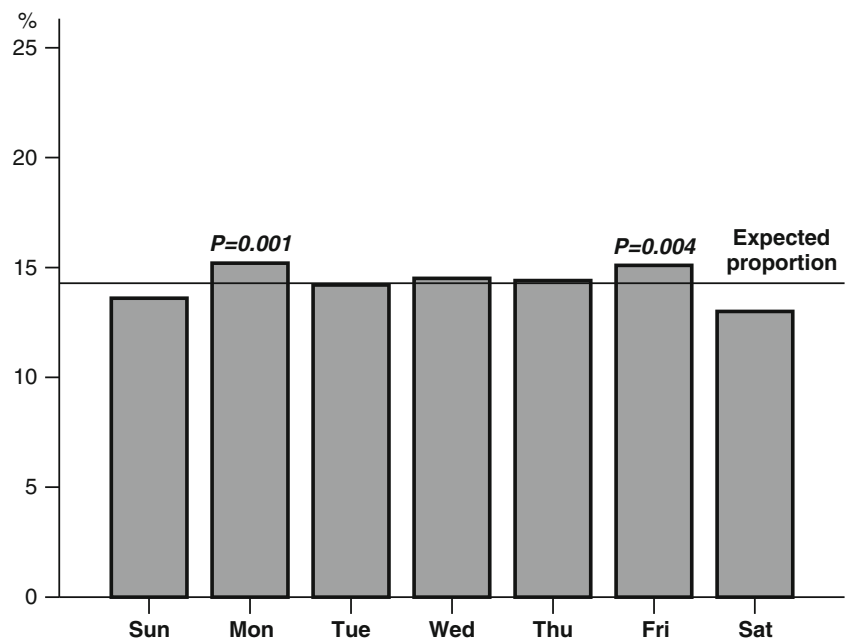
**Fig. 2** Distribution of labor admission according to day of the week

Measurements of atmospheric pressure revealed 926.0±3.5 and 926.3±3.5 hPa for P75 and control groups, respectively, with a mean difference of −0.271 (95% CI: −0.620 to +0.077). The mean humidity was 80.0±8.1% (P75) and 79.9±8.6% (control), with a mean difference of +0.089 (95% CI: −0.746 to +0.923). The mean precipitation was 4.1±11.1 mm (P75) and 3.9±10.0 mm (control), with a mean difference of +0.185 (95% CI: −0.840 to +1.210) The particulate matter (PM_{10}) mean was 41.7±23.7 μg/m^3 (P75) and 44.0±25.8 μg/m^3 (control), with a mean difference of −2.322 (95% CI: −5.179 to +0.535) and the carbon monoxide (CO) mean was 2.0±

1.4 ppm (P75) and 1.9±1.4 ppm (control), with a mean difference of +0.052 (95% CI: −0.109 to +0.213). The tidal variation mean was 1.0±0.4 m and 1.1±0.4 m in the P75 and control groups, respectively, with a mean difference of+ 0.022 (95% CI: −−0.057 to +0.013).

The predictors by multivariate logistic regression of high labor admission included increases in outdoor temperature (odds ratio: 1.742, P=0.045, 95%CI: 1.011–3.001), and decreases in atmospheric pressure (odds ratio: 1.269, P= 0.029, 95%CI: 1.055–1.483). In contrast, increases in tidal range were associated with a lower probability of high

Fig. 3 Distribution of childbirth according to month of the year
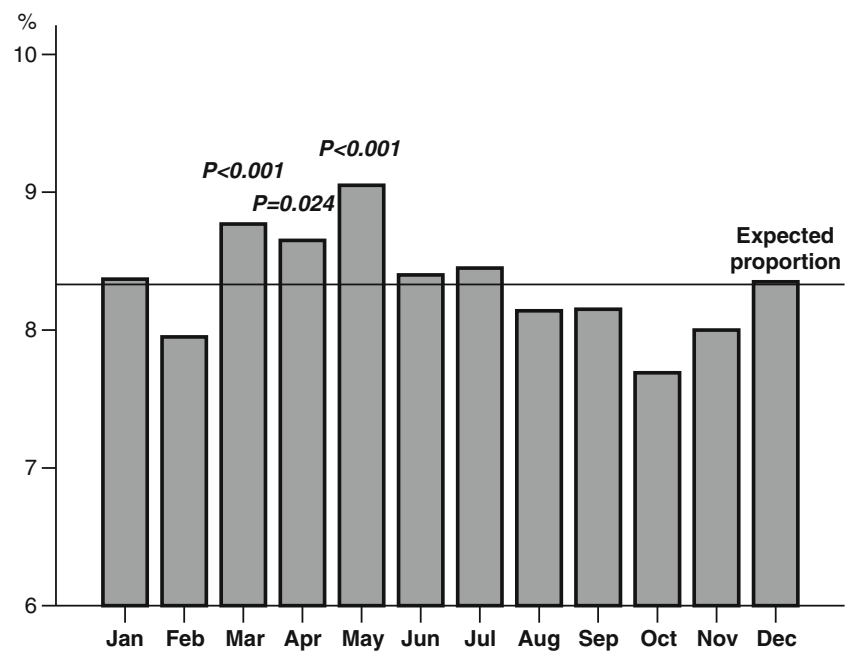
admission (odds ratio: 0.762, $P=0.030$, 95%CI: 0.515–0.999) as shown in Fig. 4. Lunar phase was not a predictor of high labor admission ($P=0.339$).

Discussion

To our best knowledge, this is the first study using a multivariate model addressed to answer practical questions about predictors of crowded delivery rooms. We found that a decrease of atmospheric pressure and an increase of outdoor temperature were predictive of high rates of labor admission. Additionally, an increase of tidal range was related to a lower probability of labor admission. In summary, an increase of 3.2°C (1.0 SD) of outdoor temperature increased by 74% the probability of more labor admission, and a decrease of 0.88 HPa (0.25 SD) increased this probability by 27%. In contrast, an increase of 18 cm (0.5 SD) in tidal amplitude decreased by 24% the probability of more labor admissions.

There are few popular beliefs concerning the influence of atmospheric pressure upon labor, probably because atmospheric pressure, as a concept, is less salient. On the other hand, published scientific studies have demonstrated that a drop in atmospheric pressure is related to increases in labor occurrence. Noller et al. (1996), in Massachusetts, USA, found decreases in atmospheric pressure to reduce the onset of labor. King et al. (1997), in Texas, USA, found an increased rate of labor onset associated with reductions in atmospheric pressure in a sample of 162 patients. In a study of 2,278 women in Tokyo, Japan, increases of rates of the rupture of membranes and childbirth were correlated with a reduction in the atmospheric pressure (Akutagawa et al.

2007). In Illinois, USA, Hirsch et al (2010) used logistic regression models to associate onset of labor and meteorological variables such as atmospheric pressure, temperature and humidity. Examining a total of 1,088 patients, they found a statistically significant improvement in prediction of the labor; however, the magnitude of this improvement was small (1.98%).

In contrast, in Arizona, USA, Morton-Pradhan et al. (2005) did not find an association between atmospheric pressure and labor onset. In Texas, USA, Driscoll (1995) found an association between cold front, wind speed, and drops in atmospheric pressure with labor onset rates over a period of 912 days using a univariate analysis. Days with increases of atmospheric pressure correlated with a reduction of 18% in the rate of childbirth. A direct effect of atmospheric pressure upon the uterine-fetus system seems unlikely. A more probable mechanism would be the stimulation of baroceptors resulting in hormonal release, such as oxytocin and corticosteroids, leading to uterine contractions. Obviously, the physiological mechanisms underlying the association of atmospheric pressure and labor onset require further study.

The environmental conditions could trigger the uterine contractions through oxytocin release. The hypothalamus produces two nonapeptide hormones, vasopressin and oxytocin, that are structurally similar except for two amino acids. Additionally, some factors that affect primarily vasopressin secretion could have some impact in oxytocin release, e.g., a drop in blood pressure (Robertson 2001). As we know, atmospheric pressure influences blood pressure. Consequently, hypothalamic oxytocin release could start the delivery labor. However, this physiologic explanation is as yet merely speculative.

Fig. 4 Environmental influence in labor admission
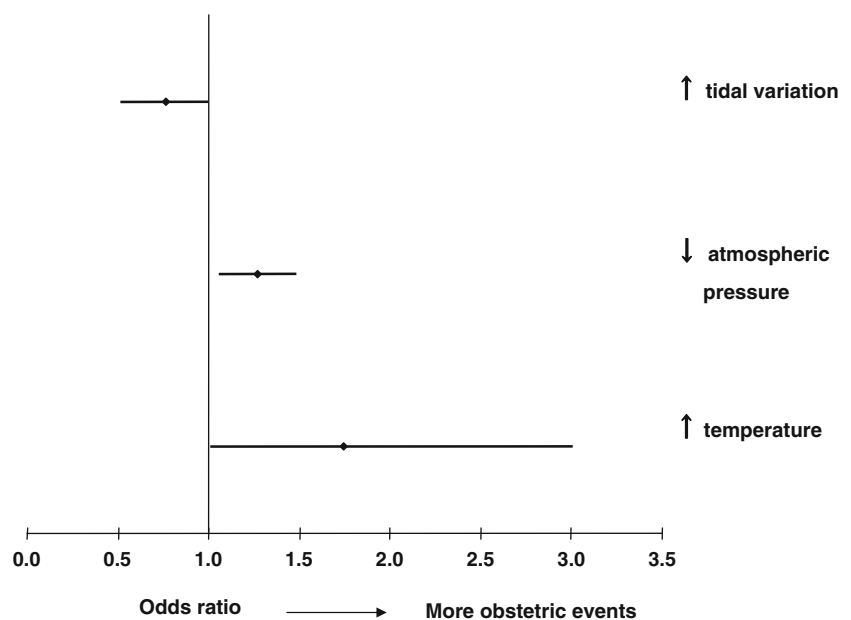
In relation to outdoor temperature, Morton-Pradhan et al. (2005) did not find any association with childbirth. Newborns have immature thermo-regulation; therefore, outdoor temperatures around 37°C could possibly be a biological advantage to a newborn, and increase survival probability. The concern is temperatures below 37°C, because there are few places in the world where temperature is above this level. In accordance with this concept, the newborn is maintained dry and warm in the delivery unit, via contact with the mother's body, and artificial heating. Therefore, temperature may be an important influence upon childbirth outcome.

We considered the value of this study is the reporting the predictors of crowded delivery rooms in an easy interpretable way by obstetric professionals, using a multivariate model, different from the above cited studies.

It has been believed that lunar phases can influence labor onset, specifically that the full and new moon phases could induce uterine contractions. However, findings regarding this subject are controversial. Study in Italy (Ghiandoni et al. 1998) has documented a higher rate of childbirths during the periods of full moon. On the other hand, two studies from the USA (Arliss et al. 2005; Morton-Pradhan et al. 2005) and one from Germany (Kuss and Kuenh 2008) did not show any lunar influence upon labor onset.

The moon could influence labor through gravitational forces, such that the increased gravitational force during full and new moons could hold the fetus, amnion, and uterus further from the cervix, making labor more unlikely. In the studies mentioned above, univariate analyses were carried out to assess the lunar influence upon labor onset. In contrast, we used a multivariate analysis, and did not find any association between lunar phases and labor onset. The assessment of lunar influence by the presence of the moon in the sky is, however, an indirect measurement. In addition, we analyzed lunar influence directly by measuring the ocean tidal range and, using logistic regression, found an association between greater tidal ranges and a lower probability of high labor admission rates. These data demonstrated that a change of one standard deviation in tidal range (0.35 m) was associated with a 24% reduction in the probability of high labor admission rates. We believe that the sensitivity of the data analysis method used allowed us to detect this small, yet significant, difference.

Labor is an active process accompanied by uterine contractions, and if lunar gravitational force influences labor, it will be by hormonal mechanisms. Interestingly, we found that a greater tidal range, which occurs at full and new moons, predicted a lower occurrence of a high labor rate. This finding contradicts popular belief.

Ronca (2003) studied pregnant rats in zero gravity and observed a two-fold increase in uterine contractions in relation to the control group, but without changes in labor duration. The author argued that zero gravity may make it difficult for contraction substances to bind to uterine receptors. Further studies concerning the influence of gravitational force on full-term pregnancy are necessary.

Childbirth may be synchronized by environment factors, becoming either delayed or advanced, which results in peaks of labor admissions during particular periods, days, or months. It is possible that this synchrony is a factor related to improved childbirth outcomes.

In the current study, a peak in spontaneous labor admission occurred in the periods between 0700 and 1300 hours. A previous study has shown a higher rate of labor onsets and childbirth occurring in the nocturnal period (Seron-Ferre et al. 1993). These authors argued that a higher frequency of nocturnal labor may be related to increases of blood levels of melatonin, a hormone involved in the synchronization of the sleep–wake cycle with the light–dark cycle. Hirsch et al (2010) found a period of onset of labor between 0300 and 0600 hours, with lower temperatures perhaps explaining the beginning of labor being more frequent at dawn. The results of this study may reflect the possibility that women unconsciously delay their arrival at the hospital until dawn.

In addition to the light–dark cycle, weekends tend to synchronize childbirth. We found a peak in labor admission rates on both Mondays and Fridays. Childbirth rates can also be modulated by human behavior and social interactions. The availability of obstetric care is not a determinant of these peaks, since the labor ward is always open. A modern way of life could influence the timing of childbirth by conforming to commercial and working schedules, even in labor admission.

There is a strong popular belief in Brazil that childbirth rates peak in November as a consequence of increased sexual intercourse during the Carnival festivities in February. However, the present study showed that childbirth rates peak in March, April, and May.

Cesario (2002) has found higher birthrates in September, which could result from "the Christmas Effect". This effect postulates that festivities and cold weather in the winter culminate in this peak. Our data showed that birth rate peaks occurred between March and May. Therefore, the conception might have occurred between June and August. In the southern hemisphere, this period corresponds to winter and there are no festivities. Consequently, these birthrates peaks could more related to winter than to festivities.

Practical implications

The ability of hospital administrators to predict periods of high admission rates for labor would greatly help in planning staffing, training, and supply needs. One example

could be providing 20% more multiprofessional staff on Monday and Friday mornings. Another possibility is not allowing professional vacations in months of childbirth peaks. It is more complex using environmental conditions to predict staff, as it would be necessary to link meteorological information and 2-day response changes in staff levels.

The climate of São Paulo, Brazil, is considered subtropical (Cwa type, according to Köppen), and frequently presents a cold front. Variations of atmospheric pressure and temperature can have a cycle of 7 days (Kousky 1979), and the length of this cycle could lead to confusion with lunar phases in terms of a relationship with higher admissions for childbirth. Further studies should be done to clarify this matter.

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