# Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy

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## Abstract

**Objective:** The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women.

**Material and Methods:** Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5-minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed.

**Results:** In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05).

**Conclusion:** As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby. (J Turk Ger Gynecol Assoc 2024; 25: 7-12)

**Keywords:** Radiofrequency electromagnetic field, specific absorption rate, newborn, small for gestational age, pregnancy

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## Introduction

With the development of the technology, cell phones have started to play an important role in our lives and are in widespread use (1). Cell phone use has increased during the last decades, with the number of cell phone users exceeding 4.5 billion and the number of smart phone users reaching 2.87 billion.

Cell phone technology is based on the transmission of voice, text, and images via radiofrequency electromagnetic fields (RF-EMFs). Due to the development of wireless local area networks, Bluetooth, and digitally enhanced wireless communications, the RF-EMF exposure rate is increasing (2). Since cell phones are used frequently, many scientific studies have been conducted investigating the effects of RF-EMFs on health and their relationship with health problems (3-5). The International Agency for Research on Cancer classified RF-EMFs as a possible carcinogen for humans in 2011 (6).

The rate of electromagnetic energy that is absorbed by body tissues is expressed as the specific absorption rate (SAR) (7).

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This value is related to the increase in temperature of body tissues. SAR is a measure showing the amount of energy absorbed, defined as Watts per kilogram of the body (8). It is closely related to the distance to the source. The magnitude of exposure decreases rapidly as the distance increases (9). It is also thought that exposure to this type of radiation may also cause adverse effects through free radical production without an increase in tissue temperature (10). In order to reduce these negative effects, the RF-EMFs associated with cell phone use have been reduced by the latest technological developments (such as 3G and 4G). However, there has been an increase in the duration of cell phone use (11).

There are studies that have concluded that cell phone calling and texting caused low abdominal and fetal exposure (12,13). In addition, an experimental study conducted in humans has shown that abdominal RF-EMF exposure can affect placental function (14). The studies concerning the effects of cell phone exposure during pregnancy and the effects on neonatal outcomes produced conflicting results regarding gestational age and low birth weight (15,16).

Different brands or even different models of the same brands of cell phones are known to have different SAR values (17). To the best of our knowledge, there is no published study that has investigated the effects of varying SAR levels of cell phones used during pregnancy on the pregnancy or neonatal outcomes.

In this retrospective study, the aim was to evaluate the demographic characteristics of the study population and neonatal outcomes in terms of specific cell phone SAR levels and daily time spent on cell phones during pregnancy. It was also planned to evaluate the effect of SAR levels and daily duration of cell phone use on giving birth to a small for gestational age (SGA) baby.

## Material and Methods

Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. The KTO Karatay University of Ethics Committee provided ethical approval for the present research (approval number: 2021/019, date: 09.02.2021). Written informed consent was obtained from all patients.

The gestational weeks of the women, the birth weight, birth height, head circumference, sex, neonate postpartum resuscitation requirement, 5-minute APGAR score, and health status data of the newborn babies, and the type of delivery were recorded. The phone numbers of the pregnant women included in the study were obtained from hospital records. The women who agreed to participate in the study were questioned about the presence of accompanying illnesses, the presence of problems during pregnancy follow-up, phone use during pregnancy, whether they used the same phone during pregnancy, the model of the phone they used, and the average daily phone use time, including texting, calling, and social media, during pregnancy.

SAR levels were recorded according to the brands and models of the phones (18).

Babies born below the $10^{th}$ percentile of birth weight standards for gestational age were defined as SGA, babies born between the $10^{th}$ and $90^{th}$ percentile were grouped as appropriate for gestational age, and those above the $90^{th}$ percentile were grouped as large for gestational age. The term "symmetrical SGA" refers to babies in whom all percentile values are below the $10^{th}$ percentile while asymmetrical SGA is used when the babies birth weight is below the $10^{th}$ percentile but there is a relative sparing of growth of the brain, cranium, and long bones (19).

### Exclusion criteria

Infants born at any hospital except Konya City Hospital, infants of refugees, women with concomitant diseases during pregnancy (including diabetes mellitus, preeclampsia, and hypertension), women with multiple pregnancies, women who did not agree to participate in the study, infants with conditions affecting their birth weight, pregnant women whose data could not be accessed through the hospital data system, and women who used more than one phone with different SAR values during pregnancy were excluded from the study.

### Statistical analysis

The statistical analyses were performed using IBM SPSS, version 22 (IBM Inc., Armonk, NY, USA). Data showing normal distribution were evaluated with an independent samples t-test, while variables without normal distribution were analyzed using the non-parametric Mann-Whitney U test. Categorical variables were analyzed using Fisher's exact and Pearson's chi-square tests. Results were expressed as mean ± standard deviation for normal distributions or median and $25^{th}$-$75^{th}$ percentile interquartile range. In addition, receiver operating characteristic (ROC) curve analysis was conducted to determine the cut-off value for the SAR level in babies who were SGA. P-values <0.05 were considered statistically significant.

## Results

During the study period, 409 of 2286 pregnant women were excluded from the study as they were refugees. The data of the remaining 1877 pregnant women were accessed. In total 144 of these were excluded from the study as 125 had concomitant diseases and 19 of the pregnancies were multiple gestations (twins in 18, triplets in 1). In addition, 73 women declined to participate in the study. The phone numbers of 67 women could not be obtained and 26 used two or more phones with different SAR levels. Furthermore, 17 were not using cell phones and 51 did not know the model of their cell phone. Four babies were excluded from the study due to additional conditions [Down syndrome (n=3) and achondroplasia (n=1)]. The remaining 1495 pregnant women and their babies were included in the study. The demographic and neonatal data of these 1495 pregnant women and their babies are given in Table 1.

Seven hundred and forty-four (49.8%) of the babies included in the study were male and 751 (50.2%) were female. The analyzed pregnancy was the median third (2-4) pregnancies of the women. Twenty of these babies (1.3%) needed resuscitation while 208 of them (13.9%) were SGA (Table 1). The babies were divided into two groups: SGA (n=208) and non-SGA (n=1287). The comparison of mothers in these two groups according to their time spent on the phone and the SAR levels of the phones they used during pregnancy is given in Table 2.

Time spent on the phone for the mothers of the SGA babies was similar to the time spent on the phone by mothers of non-SGA babies (p=0.969). In mothers who used higher SAR value phones, the rate of having an SGA baby was significantly higher (p=0.001) (Table 2). Since the incidences of exitus and stillbirths (16 babies) were low, no comparison could be made between these two groups.

When the maternal body mass index was compared between the SGA and non-SGA groups, no difference was found (p=0.706). There was no difference between the groups when the duration of exercise during pregnancy (absent, intermittent, regular), socioeconomic status (low, medium, high) and school graduation degree (illiterate, primary/secondary school, high school/university) were compared (respectively p=0.962; p=0.077; p=0.671). There was no difference between the groups in terms of smoking during pregnancy (p=0.054) (Table 2).

To determine the relation between the SAR values of the phones used and the probability of giving birth to an SGA baby, ROC curve analysis was performed. The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726) (Figure 1).

SGA babies were then further divided into two groups; symmetrical SGA (n=79; 38.0%) and asymmetrical SGA (129; 62.0%). The data on the SAR values of the phones used by mothers of asymmetrical and symmetrical SGA babies during

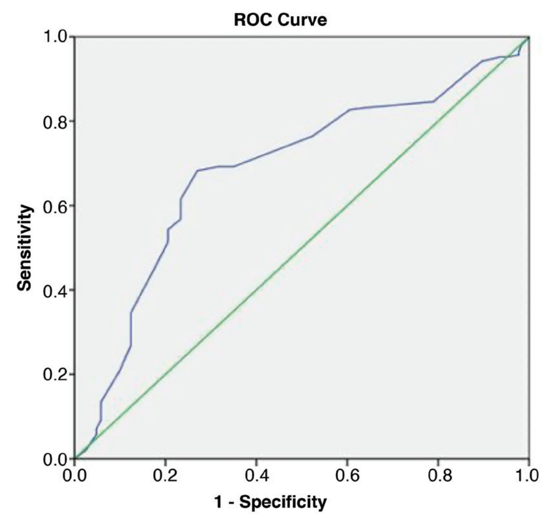


**Figure 1. ROC curve analysis of the relationship between SAR value and SGA**

***ROC: Receiver operating characteristic, SGA: Small for gestational age, SAR: Specific absorption***

**Table 1. Demographic and neonatal characteristics of the pregnant women and their babies**

| **Characteristics** | **n (%)** |
|---|---|
| Gender (male/female) | 744/751 (49.8/50.2) |
| Number of pregnancies (gravida)* | 3 (2-4) |
| Gestational age (weeks)* | 39 (38-40) |
| Birth weight (grams)* | 3200 (2880-3500) |
| Birth length (cm)* | 50 (49-52) |
| Birth head circumference (cm)* | 35 (34-35) |
| Route of delivery (vaginal/cesarean section) | 881/614 (58.9/41.1) |
| 5-min Apgar* | 10 (9-10) |
| Resuscitation need (+) | 20 (1.3) |
| Alive/exitus/stillbirth | 1479/6/10 (98.9/0.4/0.7) |
| SGA/AGA/LGA | 208/1103/184 (13.9/73.8/12.3) |
| Phone SAR level (W/kg)* | 1.09 (1.02-1.4) |
| Daily time spent on phone (minutes)* | 190 (150-240) |

*: Median (interquartile range: 25-75), SGA: Small for gestational age, AGA: Appropriate for gestational age, LGA: Large for gestational age, SAR: Specific absorption rate

pregnancy and the duration of time spent on the phone are shown in Table 3. Although both phone SAR values and the time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p=0.109 and p=0.162, respectively) (Table 3).

Two hundred four of the babies were preterm. The comparison of the SAR values and time spent on the phone in terms of preterm delivery is shown in Table 4. Both the SAR values and time spent on the phone were higher for the preterm babies compared to the term babies, but again the difference was not significant (respectively p=0.473 and p=0.267) (Table 4).

## Discussion

Cell phone use has rapidly increased during the last several decades and the negative effects of RF-EMFs used in cell phone technology on health are a subject of research. RF-EMF exposure during pregnancy has been investigated with conflicting results (2,15). Daşdağ et al. (20) found that the course of pregnancy was not affected by exposure to RF-EMF during pregnancy in rats, but the offspring of the rats exposed to the RF-EMF had lower birth weight. Shirai et al. (21) investigated the effects of an RF-EMF applied to pregnant rats at different frequencies and discovered that it had no negative results on the ongoing pregnancy or offspring of the rats. Yüksel et al. (22) found that RF-EMF exposure could cause low birth weight in rats through increased intrauterine oxidative stress.

**Table 2. Gestational age, birth weight, and telephone use data of mothers of SGA and non-SGA babies**

| Characteristics | SGA babies (n=208) n (%) | Non-SGA babies (n=1287) n (%) | p |
|---|---|---|---|
| Gestational age (weeks)* | 39 (37.1-39.8) | 39 (38-40) | 0.303 |
| Birth weight (grams)* | 2200 (2052-2450) | 3280 (3015-3560) | 0.001 |
| Pre-pregnancy weight (kg) * | 63 (49-68) | 62 (47-70) | 0.997 |
| Weight gain during pregnancy (kg) * | 12 (8-16) | 12.5 (7.5-17) | 0.965 |
| Body mass index* | 19.9 (18.7-29.3) | 20.9 (18.9-28.8) | 0.706 |
| Phone SAR level (W/kg)* | 1.42 (1.09-1.49) | 1.09 (1.02-1.26) | 0.001 |
| Daily time spent on phone (minutes)* | 190 (142.5-240) | 190 (150-240) | 0.969 |
| Physical exercise | Absent: 194 (93.3)<br>Intermittent: 10 (4.8)<br>Regular: 4 (1.9) | Absent: 1206 (93.7)<br>Intermittent: 66 (5.1)<br>Regular: 15 (1.2) | 0.962 |
| Education | Illiterate: 1 (0.5)<br>Primary/middle school: 183 (88.0)<br>High school/university: 24 (11.5) | Illiterate: 1 (0.08)<br>Primary/middle school: 1235 (96.0)<br>High school/university: 51 (3.92) | 0.671 |
| Socioeconomic status (low) | 195 (93.7) | 1156 (89.8) | 0.077 |
| Smoking during pregnancy | 4 (1.9) | 7 (0.5) | 0.054 |

*: Median (interquartile range: 25-75), SGA: Small for gestational age, SAR: Specific absorption rate

**Table 3. Phone use data of mothers of asymmetrical and symmetrical SGA babies**

| Characteristics | Babies with symmetrical SGA, (n=79) | Babies with asymmetric SGA, (n=129) | p |
|---|---|---|---|
| Phone SAR level (W/kg)* | 1.42 (1.13-1.51) | 1.4 (1.07-1.49) | 0.109 |
| Daily time spent on phone (minutes)* | 210 (150-250) | 190 (140-240) | 0.162 |

*: Median (interquartile range: 25-75), SGA: Small for gestational age, SAR: Specific absorption rate

**Table 4. Comparison of the SAR values and time spent on the phone in terms of preterm delivery**

| Characteristics | Preterm babies, (n=204) | Term and post-term babies, (n=1291) | p |
|---|---|---|---|
| Phone SAR level (W/kg)* | 1.12 (1.05-1.45) | 1.09 (1.02-1.42) | 0.473 |
| Daily time spent on phone (minutes)* | 200 (160-240) | 190 (150-240) | 0.267 |

*: Median (interquartile range: 25-75), SAR: Specific absorption rate

In their animal study Sommer et al. (23) did not detect any harmful effects on the development of the offspring. Mortazavi et al. (24) found that exposure to ionizing radiation during pregnancy did not increase the risk of low-birth weight. Benson and Shulman (25) reported an increase in the frequency of low birth weight infants in regions where there were high levels of natural radiation exposure. Although there are conflicting results in the literature, in the present study the mothers of SGA fetuses were significantly more likely to use cell phones with higher SAR levels.

ROC analysis identified a cut-off value of the SAR level of 1.23 W/kg for giving birth to an SGA baby with 69.3% sensitivity and 73.0% specificity. To the best of our knowledge, our study is the first to determine a cut-off level. Baste et al. (16) reported that medium and high cell phone exposure during pregnancy decreased the risk of preeclampsia but this was not consistent with the other findings of the present study. Since preeclampsia is a factor known to affect the birth weight of newborn babies, we excluded all pregnant women with any pregnancy complications, including preeclampsia, from the study. Therefore, we were unable to make a comparison regarding the effect of SAR value on the development of preeclampsia.

Nagaoka et al. (12) found that the SAR level to which the fetuses were exposed was lower than that to which the pregnant women were exposed. In addition, Luo et al. (14) found that RF-EMF exposure may change the protein structure of the chorionic villi during early pregnancy, which is the most sensitive stage of intrauterine life, and could affect cell proliferation. Although the difference was not significant, in our study the mothers of babies with symmetrical SGA were found to have used cell phones with higher SAR levels and spent more time on the phone during pregnancy than the mothers of babies with asymmetrical SGA. This finding supports the suggestion that SAR exposure in early pregnancy may cause the development of symmetrical SGA.

Tsarna et al. (2) stated that cell phone use during pregnancy might be associated with the likelihood of preterm delivery. This is supported by the findings reported by Col-Araz (15). These findings are not consistently reported, with Baste et al. (16) finding no association between cell phone exposure and preterm delivery. In the present study, although both the SAR values of phones used during pregnancy and the duration of phone use were higher in preterm deliveries compared to term deliveries, the difference was not significant.

It was planned to investigate the association between the SAR levels of phones used during pregnancy and the duration of cell phone use and the stillbirth rate. However, this evaluation was not possible as the number of stillborn babies was low in our study.

Shen et al. (26) found a rate of SGA births of 5.74%, whereas in the present study, this rate was higher (13.9%). We attribute this difference to the fact that our hospital was a tertiary healthcare institution and that more complicated cases were referred to our hospital. In our study, the median time spent on the phone by the pregnant women was 190 minutes. As the time spent with devices using RF-EMFs increases day by day, more research is required on this issue.

### Study limitations

One limitation of our study is that the pregnant women could not be examined in two groups according to less time and more time spent on the phone because of the generally long cell phone daily use time. The retrospective design of our study is the other limitation. Prospective studies with a large number of cases and comparing the effects of SAR levels according to the periods of pregnancy (first, second, and third trimester) are warranted.

## Conclusion

As the SAR levels of cell phones used during pregnancy increased, the likelihood of giving birth to an SGA baby increased significantly. ROC curve analysis identified a SAR cut-off value of 1.23 W/kg with 69.3% sensitivity and 73.0% specificity. However, there was no effect on the likelihood of SGA in terms of time spent on the phone in this population.

***Ethics Committee Approval:*** *The KTO Karatay University of Ethics Committee provided ethical approval for the present research (approval number: 2021/019, date: 09.02.2021).*

***Informed Consent:*** *Written informed consent was obtained from all patients.*

***Author Contributions:*** *Surgical and Medical Practices: M.B.; Concept: M.B.; Design: M.B.; Data Collection or Processing: M.B., F.K.Y.; Analysis or Interpretation: M.B., F.K.Y.; Literature Search: M.B., F.K.Y.; Writing: M.B., F.K.Y.*

***Conflict of Interest:*** *No conflict of interest is declared by the authors.*

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## References

1. Divan HA, Kheifets L, Olsen J. Prenatal cell phone use and developmental milestone delays among infants. Scand J Work Environ Health 2011; 37: 341-8.

2. Tsarna E, Reedijk M, Birks LE, Guxens M, Ballester F, Ha M, et al. Associations of Maternal Cell-Phone Use During Pregnancy with Pregnancy Duration and Fetal Growth in 4 Birth Cohorts. Am J Epidemiol 2019; 188: 1270-80.
3. Bortkiewicz A. Health effects of Radiofrequency Electromagnetic Fields (RF EMF). Ind Health 2019; 57: 403-5.
4. Kim JH, Lee JK, Kim HG, Kim KB, Kim HR. Possible Effects of Radiofrequency Electromagnetic Field Exposure on Central Nerve System. Biomol Ther (Seoul) 2019; 27: 265-75.
5. Guxens M, van Eijsden M, Vermeulen R, Loomans E, Vrijkotte TG, Komhout H, et al. Maternal cell phone and cordless phone use during pregnancy and behaviour problems in 5-year-old children. J Epidemiol Community Health 2013; 67: 432-8.
6. IARC. 'IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans', Accessed July 16, 2018. 2011. http://www.iarc.fr/en/mediacentre/pr/2011/pdfs/pr208_E.pdf
7. Wall S, Wang ZM, Kendig T, Dobraca D, Lipsett M. Real-world cell phone radiofrequency electromagnetic field exposures. Environ Res 2019; 171: 581-92.
8. Challis LJ. Mechanisms for interaction between RF fields and biological tissue. Bioelectromagnetics 2005; Suppl 7: S98-S106.
9. Zamanian A, Hardiman C. Electromagnetic radiation and human health: A review of sources and effects electromagnetic radiation and human health: A review of sources and effects. High Frequency Electronics 2005; 16-26.
10. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields. IARC Monogr Eval Carcinog Risks Hum 2013; 102: 1-460.
11. Lauer O, Frei P, Gosselin MC, Joseph W, Röösli M, Fröhlich J. Combining near- and far-field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: a reference case. Bioelectromagnetics 2013; 34: 366-74.
12. Nagaoka T, Togashi T, Saito K, Takahashi M, Ito K, Watanabe S. An anatomically realistic whole-body pregnant-woman model and specific absorption rates for pregnant-woman exposure to electromagnetic plane waves from 10 MHz to 2 GHz. Phys Med Biol 2007; 52: 6731-45.
13. Tateno A, Tanaka K, Nagaoka T, Saito K, Watanabe S, Takahashi M, et al. Specific absorption rates of pregnant females and their fetuses from simple and realistic electromagnetic sources. IEICE Commun Express 2014; 3: 55-60.
14. Luo Q, Jiang Y, Jin M, Xu J, Huang HF. Proteomic analysis on the alteration of protein expression in the early-stage placental villous tissue of electromagnetic fields associated with cell phone exposure. Reprod Sci 2013; 20: 1055-61.
15. Col-Araz N. Evaluation of factors affecting birth weight and preterm birth in southern Turkey. J Pak Med Assoc 2013; 63: 459-62.
16. Baste V, Oftedal G, Møllerløkken OJ, Mild KH, Moen BE. Prospective study of pregnancy outcomes after parental cell phone exposure: the Norwegian Mother and Child Cohort Study. Epidemiology 2015; 26: 613-21.
17. Lee AK, Hong SE, Kwon JH, Choi HD, Cardis E. Mobile phone types and SAR characteristics of the human brain. Phys Med Biol 2017; 62: 2741-61.
18. Bundesamt für Strahlenschutz. Available from: http://www.bfs.de/sar-werte-handy
19. Sharma D, Shastri S, Farahbakhsh N, Sharma P. Intrauterine growth restriction - part 1. J Matern Fetal Neonatal Med 2016; 29: 3977-87.
20. Daşdağ S, Akdağ MZ, Ayyildiz O, Demirtas OC, Yayla M, Sert C. Do cellular phones alter blood parameters and birth weight of rats? Electro Magnetobiol 2000; 19: 107-13.
21. Shirai T, Wang J, Kawabe M, Wake K, Watanabe SI, Takahashi S, et al. No adverse effects detected for simultaneous whole-body exposure to multiple-frequency radiofrequency electromagnetic fields for rats in the intrauterine and pre- and post-weaning periods. J Radiat Res 2017; 58: 48-58.
22. Yüksel M, Nazıroğlu M, Özkaya MO. Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring. Endocrine 2016; 52: 352-62.
23. Sommer AM, Grote K, Reinhardt T, Streckert J, Hansen V, Lerchl A. Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: a multi-generation study. Radiat Res 2009; 171: 89-95.
24. Mortazavi SM, Shirazi KR, Mortazavi G. The study of the effects of ionizing and non-ionizing radiations on birth weight of newborns to exposed mothers. J Nat Sci Biol Med 2013; 4: 213-7.
25. Benson BW, Shulman JD. Effect of antepartum natural background radiation on infant low birth weight: A pilot study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005; 99: E22.
26. Shen ZZ, Wang YW, Ma S, Zhan YL, Wu SS, Feng YH, et al. Chinese Pregnant Women Cohort Study-Peking Union Medical College Collaborative Group. [Risk factors for preterm birth, low birth weight and small for gestational age: a prospective cohort study]. Zhonghua Liu Xing Bing Xue Za Zhi 2019; 40: 1125-9.