Detecting Rates, Trends and Determinants of Caesarean Section Deliveries in Iran Using Generalised Additive Mixed Models

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DOI: 10.2427/11821
Accepted on June 16, 2016

ABSTRACT

Background: The study aims to investigate the trend of caesarean section and its related factors through the recent years in Hamadan province, Iran.
Methods: The study data contains delivery information from hospitals in Hamadan recorded from 2001 to 2014. The data were analysed through the generalised additive mixed models using R software (v. 3.2.2).
Results: In this study it is shown that caesarean rate was about 42%. According to the results, the trend of caesarean deliveries almost increased in the recent years. A significant relationship was found between average age and elective caesarean rate, however, pregnancy rate did not have a significant effect on elective caesarean rate.
Conclusion: Caesarean section rate was higher than the limit allowed by the World Health Organization (WHO) that is 15%. Although caesarean delivery is preferred to natural vaginal delivery when the mother's or infant's life is at risk, it should not replace natural delivery for any reason. Natural vaginal delivery can be promoted by providing the knowledge about the advantages of natural delivery and complications of caesarean section.

INTRODUCTION

Caesarean section, which is the most common mode of delivery is performed with the mother's choice or due to medical reasons including: repeated caesarean section, foetal distress, cephalopelvic disproportion, abnormal presentation, placenta previa, multiple births and dystocia [1-3]. When a mother's or an infant's life is in danger and the pregnant woman cannot go through a natural vaginal delivery, caesarean section can facilitate the delivery process. Yet, this surgery is accompanied by some complications such as adhesions, anaesthesia complications, severe infection, loss of blood, probability of high-risk pregnancies in future, placenta previa, long duration of delivery, preterm birth and low birth weight [4-6]. In addition, studies have shown that the cost, particularly in the private sector, length of hospital stay, medications and complications of caesarean delivery are considerably higher compared to natural vaginal delivery [7-8]. However, Iranian women tend to choose caesarean delivery due to their fear of pain and lack of knowledge about natural and caesarean deliveries [9-10]. In the two recent decades, caesarean delivery has become so common among the women that the rate of caesarean delivery in Iran is 4 times higher than the global standard. This has increased the authorities' concern about the growing trend of caesarean deliveries. If pregnant women are informed about the 2-7-fold higher risk of caesarean section for both the mother and the foetus as well as the 5-10-fold higher rate of disability after caesarean delivery compared to natural vaginal delivery, they may prefer natural delivery to caesarean section [11].

In spite of the policies devised by the health system, the increasing trend of caesarean deliveries in the recent 8 years shows the necessity to take further measures in this regard. According to statistics, 46.3% of the deliveries in Hamadan province were carried out through caesarean section in 2011; it shows a 4.3% increase compared to 2009 [4]. Besides, 90% of the deliveries in private hospitals were performed through caesarean surgery, while the World Health Organization (WHO) has announced that the annual rate of caesarean section must not exceed 15% of all deliveries [12].

Several studies have suggested the use of generalised linear model (GLM) and generalised linear mixed model (GLMM) to assess the trend and related factors of caesarean section delivery [13-14].

Generalised linear mixed model (GLMM) and Generalised additive mixed model (GAMM) can be used to investigate a clustered count variable such as caesarean number through time [15].

A major limitation of the GLMMs is that they use parametric functions to model covariate effects. However, sometimes the relationship between the link function of the mean response and covariates may be in a complicated form and appropriate functional forms of the covariates may be unknown. The GAMM approach relaxes the limitation that the relationship between outcome and covariates is known by allowing it to incorporate unknown smooth functions of a subset of covariates [16].

Since the rate of caesarean deliveries has changed over time and GAMM is more flexible than GLMM, GAMM was employed in this study in order to assess the trend of caesarean deliveries in the recent 14 years in Hamadan. By identifying the trend and effective factors in this phenomenon, policies can be made and necessary training can be provided in order to reduce the rate of unnecessary caesarean deliveries.

METHODS

The present longitudinal study was conducted on the rate of caesarean deliveries in Hamadan province. Hamadan province with an area of 19493 km^2 is located in the west of Iran. According to the census of 2011, the population of this province is 1,758,268. It is the 14th largest province in Iran in terms of the number of population and the 23rd largest in terms of area [17-18]. Data for the study were obtained through the forms filled out by 15 hospitals in the province once a year from 2001 to 2014 and were given to the health deputy of the province.

The response variable in this study is the ratio of elective caesarean deliveries to all deliveries carried out in each of the hospitals in Hamadan province. Average age and pregnancy rates in the study hospitals and time (year) were considered as independent variables. In each hospital, the "pregnancy rate" is the average number of pregnancies for each woman. In order to determine the trend and effects of these factors on the rate of caesarean deliveries, Poisson regression model for caesarean rate with log link function and offset was utilised.

Poisson additive regression model:

A Poisson additive regression model for count data is defined as follows [19-20]:

$$log(\mu_i)=x_i\beta+f_1(x_1)+f_2(x_2)+\ldots+f_p(x_p) \qquad (1)$$

$$Y_i \sim Poisson(\mu_i)$$

$$P(Y_i = y_i) = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!}$$

$$E(Y_i) \sim \mu_i$$

Where, Y_i is the response at time i, X_i is a vector of parametric covariates and β is the parameter vector containing regression coefficients. Function f(.) is the smooth function and should be estimated.

The rate is a count of events occurring to a particular unit of observation, divided by some measure of that unit's exposure. In the Poisson regression model for rate, an offset enters at the right-hand side of the equation as Eq. (1). Offset for the data of this study is defined as the logarithm of unit population (total delivery per hospital).

Negative binomial additive regression model:

A popular model for handling dispersion count data is negative binomial model in which outcomes Y_i is premised to have a negative binomial distribution over Poisson in Eq. (1) as follows [21-22]:

$$Y_i \sim NB(\mu_i)$$

$$P(Y_i = y_i) = \frac{\Gamma(y_i + r)}{\Gamma(r)\Gamma(y_i + 1)}\left(\frac{r}{\mu_i + r}\right)^r\left(1 - \frac{r}{\mu_i + r}\right)^{y_i}$$

$$E(Y_i) = \mu_i$$

Where r^{-1} is called over dispersion parameter. As $r^{-1}\rightarrow 0$, the negative binomial distribution converges to Poisson distribution.

In this study, the data were obtained from 2001 to 2014; therefore, the hospital-specific effect (random effect) could also be included in the model. However, the complete information of these years was not available for some of the study hospitals. Yet, one of the advantages of mixed models is that the information in all the years is not necessary for all the subjects [23]. Thus, the Poisson (or negative binomial) additive mixed model for rate is as follows:

$$log\ (\mu_i)=x_i\beta+f_1(x_1)+f_2(x_2)+\ldots+f_p(x_p)+offset+v_i \quad (2)$$

Where the random effect of v_i is considered with normal distribution (0, σ^2_v).In addition to the estimate of spline functions, parameters of the model include β and σ_v which should be estimated.

The functions and parameters of the model are estimated by maximum penalised likelihood estimator. Since the penalised likelihood equations do not have a closed form, the parameters are estimated via an iterative algorithm such as Newton-Raphson algorithm.

Numerical analyses and parameter estimations were conducted with the statistical software R (version 3.2.2) using package 'gamm'.

RESULTS

Overall, 412,159 deliveries were performed in Hamadan province of which 171,417 (41.6%) were carried out through caesarean section of which 35.4% are elective caesareans. The mean age of pregnant women in the study was about 26 (26.006±1.5768) who have experienced a second pregnancy on the average (1.921±0.25).

Figure 1 depicts the trend of caesarean deliveries in each hospital. Caesarean deliveries followed various trends in different hospitals. It shows that the random effect of hospitals may be a necessary variable in the model.

It seems that the trend was fixed and sometimes descendent, but followed an increasing trend afterwards. In addition, the highest rate of caesarean deliveries in all the periods was associated to a private hospital.

At first, parametric and non-parametric models were considered. The models are labelled M0 to M15 (Table 1). M0 and M8 are parametric linear models while the others are non-parametric models.

Table 2 summarises AICs for all the models shown in Table 1 for Poisson and negative binomial distributions, separately. Comparison of the AICs showed that M0 is a fully parametric model with a relatively poor fit. The lowest AIC is relevant to model M9 with negative binomial distribution. The model M9 is an additive model with two parametric covariates x_1 (average age) and x_2 (pregnancy rate) and a non-parametric covariate x_3 (time). The results of fitting for the best model (M9) are shown in Table 3.

The results show a significant age effect, but a non-significant effect of pregnancy rate. The adjusted R^2 (0.54) provides supporting evidence of the goodness of fit of this model.

The results also demonstrate that the smoothing trend

FIGURE 1. The probability of caesarean delivery over time.

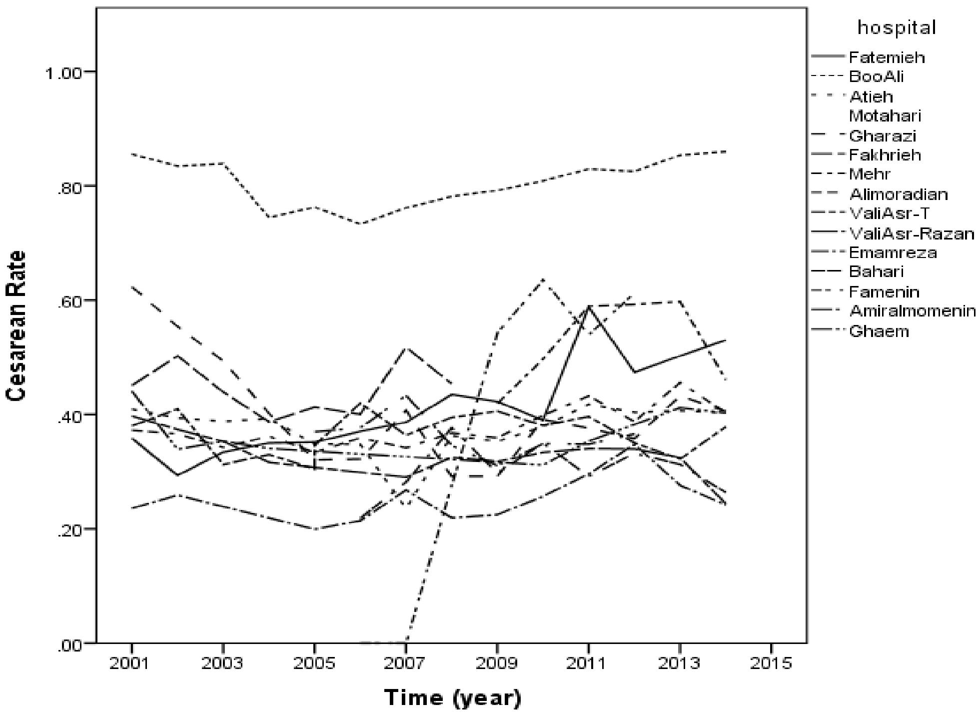


TABLE 1. Summary of equation of the models.

MODEL	EQUATION
MODELS WITH FIXED EFFECTS:	
M0	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\varepsilon_j$
M1	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_2x_2+f_3(x_3)+\varepsilon_j$
M2	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_3x_3+f_2(x_2)+\varepsilon_j$
M3	$\log(\mu_j)=\beta_0+\beta_2x_2+\beta_3x_3+f_1(x_1)+\varepsilon_j$
M4	$\log(\mu_j)=\beta_0+\beta_1x_1+f_2(x_2)+f_3(x_3)+\varepsilon_j$
M5	$\log(\mu_j)=\beta_0+\beta_2x_2+f_1(x_1)+f_3(x_3)+\varepsilon_j$
M6	$\log(\mu_j)=\beta_0+\beta_3x_3+f_1(x_1)+f_2(x_2)+\varepsilon_j$
M7	$\log(\mu_j)=f_1(x_1)+f_2(x_2)+f_3(x_3)+\varepsilon_j$
MODELS WITH FIXED AND RANDOM EFFECTS:	
M8	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\nu_j+\varepsilon_j$
M9	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_2x_2+f_3(x_3)+\nu_j+\varepsilon_j$
M10	$\log(\mu_j)=\beta_0+\beta_1x_1+\beta_3x_3+f_2(x_2)+\nu_j+\varepsilon_j$
M11	$\log(\mu_j)=\beta_0+\beta_2x_2+\beta_3x_3+f_1(x_1)+\nu_j+\varepsilon_j$
M12	$\log(\mu_j)=\beta_0+\beta_1x_1+f_2(x_2)+f_3(x_3)+\nu_j+\varepsilon_j$
M13	$\log(\mu_j)=\beta_0+\beta_2x_2+f_1(x_1)+f_3(x_3)+\nu_j+\varepsilon_j$
M14	$\log(\mu_j)=\beta_0+\beta_3x_3+f_1(x_1)+f_2(x_2)+\nu_j+\varepsilon_j$
M15	$\log(\mu_j)=f_1(x_1)+f_2(x_2)+f_3(x_3)+\nu_j+\varepsilon_j$

in years is significant (p-value<0.0001) with the fourth order polynomial (edf = 4.23).This trend is illustrated in the left panel of Figure 2. The spline function estimate of time indicates that the probability of elective caesarean decreased from 2001 to 2008. It gradually increased from 2008 to 2013 and afterwards it stayed relatively flat from 2013 to 2014.

We fitted the model with natural delivery rate as the outcome variable rather than elective caesarean rate. Right panel of Figure 2 illustrates spline function estimate of the time for the second model. This shows a descending trend for natural delivery trend from 2006 to 2011. The trend was fixed and nearly ascending to 2012 and afterwards it increased again.

DISCUSSION

There are many studies on caesarean delivery status assessment, but none of them studied the caesarean trend using additive models [24-27]. GAMs and GAMMs were used for modelling and assessing the trend in traffic-related emissions [28], analysing single case designs [29], studies of Air Pollution and Health [30], detecting contaminated birth dates [31] and etc.

The additive mixed models involve repeated measures of the same subject over time with an unknown function of time. The main advantage of these models over others is the ability to show the trend and pattern of a variable over time by controlling the correlation between subjects at the same time.

TABLE 2. Aikaike's information criterion (AIC) for models.

MODEL	AIC	
	POISSON	NEGATIVE BINOMIAL
M0	14280	2367
M1	559.2222	610.9346
M2	577.5756	604.0559
M3	592.9500	604.0559
M4	561.2530	621.7508
M5	561.2221	613.6256
M6	594.9500	606.0559
M7	563.2530	622.8298
M8	9151.693	1642.064
M9	509.5304	443.7657
M10	561.2342	504.3322
M11	561.2343	504.3322
M12	511.5304	445.7655
M13	511.5304	445.7656
M14	563.2343	506.3322
M15	513.5643	447.7658

TABLE 3. Summary statistics from fitting the best model.

Parametric coefficients	Estimate	Std. Error	t value	p-value
B_0 (intercept)	-7.3609126	2.0282344	-3.629222	0.0004
B_1 (average age)	0.1888304	0.0760883	2.481729	0.0142
B_2 (pregnancy rate)	-0.5836626	0.3734005	-1.563101	0.1202
Approximate significance of smooth terms:				
	edf	Ref.df	F	p-value
S (year)	4.23	4.23	13.28	<0.001
R-sq. (adj) = 0.54		Scale est. = 0.5395		N=163
AIC	**BIC**	**Loglik**		
443.7657	465.422	-214.8829		

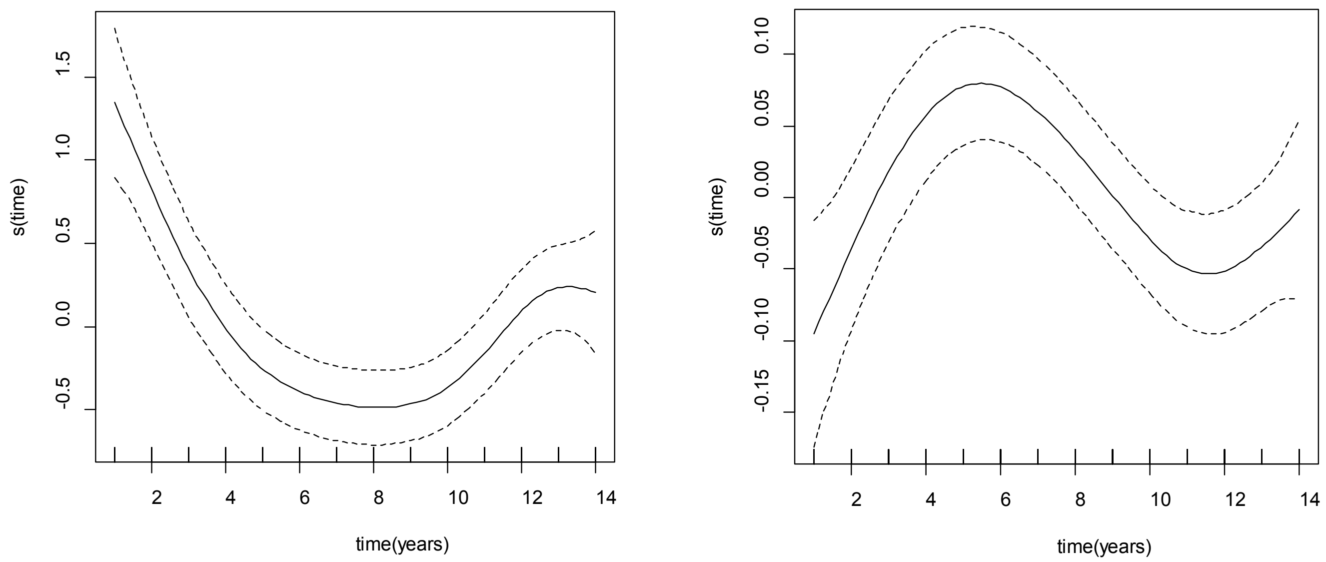
Similar to our findings, Bettegowda's study reported a significant relation between average age and the elective caesarean [32]. This is contrary to the result obtained by Davari (2014) [33].

In this study, about 42% of total deliveries were caesarean section delivery. The rate of caesarean section delivery in Iran is so much higher than the upper limit announced by the WHO (15%). In the study by Ghotbi (2014) on Iranian pregnant women from 2011 to 2012, caesarean prevalence rates were about 83% [34] and in another study in Iran, it was 27% [33].

The results showed that elective caesarean deliveries showed an almost increasing trend from 2008 to 2013 and after 2013, it was fixed and slightly descending. It seems that the implemented policies were effective in order to increase the rate of vaginal delivery in the two recent years. However, these policies could not decrease the trend of elective caesarean section. It shows a decrease in the rate of caesarean with medical reasons. Thus, further measures should be taken in order to provide women with the necessary information and training about the advantages of natural vaginal delivery and complications of caesarean delivery.

In spite of the fact that caesarean delivery is superior to natural vaginal delivery in the case where the mother's and baby's lives are in danger, it has a large number of complications [4-5,35] and should not replace natural delivery for any good reason. Overall, by providing

FIGURE 2. Regression spline functions: the left panel depicts an estimate of the time function of the model with the elective caesarean rate outcome; the right panel displays an estimate of the t function of model with natural delivery rate outcome.



the society with the knowledge of the advantages of natural delivery and complications of caesarean section, eliminating individuals' wrong attitudes regarding the advantages of caesarean delivery, eliminating the mothers' fear and anxiety towards natural delivery and investigating and preventing the physician's reasons for recommendation of caesarean delivery, unnecessary caesarean sections can be avoided and natural vaginal delivery can be promoted in the society.

Acknowledgment

This article is a part of Ph.D. thesis by Marzieh Mahmoodi in Biostatistics and it was supported by Hamadan University of Medical Sciences. We would like to thank the health deputy of the Hamadan province.

References

1. Cunningham FG. Williams obstetrics. 22 ed: McGraw-Hill Professional New York, 2005.
2. Lowdermilk DL, Perry SE, Piotrowski KA. Maternity& Women's Health Care. 9th ed. New York: Mosby Elsevier, 2007.
3. Lukanova M, Popov I. Effect of some factors on obstetrical care of women with previous cesarean section. Akush Ginekol (Sofiia) 2002; 41(6):44-8.
4. Ministry of Health, Treatment and Medical Education; 2012. Available from: www.behdasht.gov.ir/index.aspx?siteid=1&pageid=33178&newsview=62577.
5. Duff P. A simple checklist for preventing major complications associated with cesarean delivery. Obstetrics & Gynecology 2010;116(6):1393-6.
6. Nielsen TF, Hökegård K-H. Cesarean section and intraoperative surgical complications. Acta obstetrician etgynecologica Scandinavica 1984;63(2):103-8.
7. Scott J. Cesarean delivery. Danforth's obstetrics and Gynecology 2008.
8. Ebrashy A, Kassab A, Nada A, Saleh W, Soliman A. In Cairo; Egypt: Rates, Indications and Limits. KAJOG 2011;2(1):20-26.
9. Matias JP, Parpinelli MA, Cecatti JG. Factors associated with mode of delivery among primipara women with one previous cesarean section and undergoing a trial of labor. Revista da Associação Médica Brasileira 2007;53(2):109-15.
10. Amiri Farahani L, Abbasi Shavazi MJ. Review of trends and demographic factors associated with cesarean delivery rate in the last three decades. Journal of Fasa University of Medical sciences 2012;2(3):127-34.
11. Mohamadbeigi A, Tabatabaee S, Mohammadsalehi N, Yazdani M. Factors Influencing Cesarean Delivery Method in Shiraz Hospitals. IJN 2009; 21(56):37-45.
12. World Health Organization: Monitoring emergency obstetric care: a handbook. Geneva, Switzerland, 2009.
13. Declercq E, Young R, Cabral H, Ecker J. Is a rising cesarean delivery rate inevitable? Trends in industrialized countries, 1987 to 2007. Birth 2011;38(2):99-104.
14. Ye J, Betrán AP, Guerrero Vela M, Souza JP, Zhang J. Searching for the optimal rate of medically necessary cesarean delivery. Birth 2014;41(3):237-44.
15. Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith GM. GLMM and GAMM. InMixed effects models and extensions in ecology with R. Springer New York 2009;323-41.
16. Guisan A, Edwards TC, Hastie T. Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecological modelling 2002;157(2):89-100.
17. Statistical Center of Iran, 2011. Available from: http://www.amar.org.ir/Portals/2/pdf/jamiat_shahrestan_keshvar3.pdf.
18. Hamedan Municipality. Available from: http://www.hamedan.ir/

hamedan/En/Default.asp.
19. Moghimbeigi A, Eshraghian MR, Mohammad K, Nourijelyani K, Husseini M. Determinants number of cigarette smoked with Iranian adolescents: A multilevel zero inflated poisson regression model. Iranian J Publ Health 2009;38(4):91-6.
20. Mohammadfam I, Moghimbeigi A. Evaluation of injuries among a manufacturing industry staff in Iran. Journal of research in health sciences 2009;9(1):7-12.
21. Moghimbeigi A, Eshraghian MR, Mohammad K, Mcardle B. Multilevel zero-inflated negative binomial regression modeling for over-dispersed count data with extra zeros. Journal of Applied Statistics 2008;35(10):1193-202.
22. Shirmohammadi N, Moghimbeigi A, Karami M, Mahjub H, Sabouri A. Evaluation of suspected measles incidence rate trend in Iran and the affecting factors: Negative-Binomial mixed model. Koomesh 2015;16(4):595-602.
23. Hedeker D, Gibbons RD. Longitudinal Data Analysis. John Wiley & Sons Publication 2006:13-29
24. Declercq E, Young R, Cabral H, Ecker J. Is a rising cesarean delivery rate inevitable? Trends in industrialized countries, 1987 to 2007. Birth 2011;38(2):99-104.
25. Al Rifai R. Rising cesarean deliveries among apparently low-risk mothers at university teaching hospitals in Jordan: analysis of population survey data, 2002–2012. Global Health: Science and Practice 2014;2(2):195-209.
26. Alinejad V, Mahmoudi M, Khalkhali HR. The Auto-Regressive Distributed Lag (ARDL) and Error Correction Model (ECM) to Identify the Trend of Demand for Cesarean Delivery. Hermes Journal France 2013;69(1).
27. Bahonar A, Shabani A, Aghajani M. Determinants of Cesarean and its Trend inDamghan, Iran. Iranian Journal of Epidemiology 2010;6(1):33-8.
28. Carslaw DC, Beevers SD, Tate JE. Modelling and assessing trends in traffic-related emissions using a generalised additive modelling approach. Atmospheric Environment 2007;41(26):5289-99.
29. Shadish WR, Zuur AF, Sullivan KJ. Using generalized additive (mixed) models to analyze single case designs. Journal of school psychology 2014;52(2):149-78.
30. Dominici F, McDermott A, Zeger SL, Samet JM. On the use of generalized additive models in time-series studies of air pollution and health. American journal of epidemiology 2002;156(3):193-203.
31. Luo W, Gallagher M, Loveday B, Ballantyne S, Connor JP, Wiles J. Detecting contaminated birthdates using generalized additive models. BMC bioinformatics 2014 ;15(1):1.
32. Bettegowda VR, Dias T, Davidoff MJ, Damus K, Callaghan WM, Petrini JR. The relationship between cesarean delivery and gestational age among US singleton births. Clinics in perinatology 2008;35(2):309-23.
33. Davari M, Maracy M, Ghorashi Z, Mokhtari M. The Relationship Between Socioeconomic Status and the Prevalence of Elective Cesarean Section in Nulliparous Women in Niknafs Teaching Centre in Rafsanjan, Iran. Women's Health Bulletin 2014;1(2).
34. Ghotbi F, Akbari Sene A, Azargashb E, et al. Women's knowledge and attitude towards mode of delivery and frequency of cesarean section on mother's request in six public and private hospitals in Tehran, Iran, 2012. Journal of Obstetrics and Gynaecology Research 2014;40(5):1257-66.
35. Carrillo-Larco RM, Miranda JJ, Bernabé-Ortiz A. Delivery by cesarean section and risk of childhood obesity: analysis of a Peruvian prospective cohort. PeerJ 2015;3:e1046.

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