

Smoking in pregnancy: Can the first-trimester serum inflammatory markers predict adverse obstetric and neonatal outcomes?

Gebelikte sigara içiciliği: İlk trimester serum inflammatuar belirteçleri olumsuz obstetrik ve yenidoğan sonuçlarını öngörebilir mi?

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ABSTRACT

Aim: To investigate obstetric complications in pregnant women who smoke and to evaluate whether first-trimester systemic inflammatory indices can predict adverse obstetric and neonatal outcomes

Materials and Method: This retrospective study included 43 pregnant women aged between 18 and 45 years who had been smoking since prior to conception, and 44 healthy pregnant women, conducted between 2024 and 2025. Participants' demographic characteristics, obstetric outcomes (birth weight, gestational age at delivery), and neonatal outcomes (APGAR scores, NICU admission) and obstetric complications were assessed. First-trimester neutrophil-to-lymphocyte ratio (NLR), systemic immune-inflammation index (SII: $NLR \times \text{platelet count}$), systemic inflammation response index (SIRI: $NLR \times \text{monocyte count}$), aggregate index of systemic inflammation (AISI: $NLR \times \text{platelet count} \times \text{monocyte count}$), and platelet-to-lymphocyte ratio (PLR) were calculated. Receiver operating characteristic (ROC) curves were generated to evaluate the predictive value of these markers for adverse obstetric and neonatal outcomes.

Results: SII, SIRI, AISI, and NLR levels were significantly higher in the smoking group compared to controls. Pregnant women who smoked had higher rates of emergency cesarean section, adverse obstetric outcomes, and NICU admissions. ROC analysis showed that first-trimester inflammatory markers significantly predicted adverse outcomes when all participants were analyzed together; however, these markers did not demonstrate predictive value within the smoking group alone.

Conclusion: Adverse obstetric outcomes, increased NICU admissions, and elevated serum inflammatory markers were observed in pregnant women who smoked. However, these markers were found to be insufficient in predicting adverse outcomes.

Keywords: Smoking, pregnancy, inflammatory markers, obstetric complications, NICU

ÖZ

Amaç: Sigara içen gebe kadınlarla sigara içmeyenler arasında sistemik inflammatuar indekslerin karşılaştırılması ve bu indekslerin olumsuz obstetrik ve yenidoğan sonuçlarını öngörmesini değerlendirmek

Gereç ve Yöntemler: Bu retrospektif gözlemsel bir çalışma olup 2024-2025 yılı arasında 18-45 yaş aralığında gebelik öncesinden itibaren sigara kullanan 43 gebe ile 44 sigara kullanmayan gebeyi içermektedir. Katılımcıların demografik özellikleri, obstetrik sonuçları (doğum ağırlığı, doğumdaki gebelik yaşı), yenidoğan sonuçları (APGAR skorları, Yenidoğan Yoğun Bakım Ünitesi'ne (YYBU) yatış ve obstetrik komplikasyonları değerlendirilmiştir. İlk trimester nötrofil-lenfosit oranı (NLR), sistemik immün-inflamasyon indeksi (SII: $NLR \times \text{trombosit sayısı}$), sistemik inflamasyon yanıt indeksi (SIRI: $NLR \times \text{monosit sayısı}$), sistemik inflamasyonun toplam indeksi (AISI: $NLR \times \text{trombosit sayısı} \times \text{monosit sayısı}$) ve trombosit-lenfosit oranı (PLR) hesaplandı. Olumsuz obstetrik ve neonatal outcome öngörü değerini değerlendirmek için Alıcı İşletim Karakteristiği (ROC) eğrileri oluşturuldu.

Bulgular: SII, SIRI, AISI ve NLR düzeyleri, kontrol grubuna kıyasla sigara içen grupta önemli ölçüde daha yüksekti. Sigara içen hamile kadınlarda acil sezaryen oranı, olumsuz obstetrik sonuçlar ve YYBU yatış daha yüksekti. ROC analizi, tüm katılımcılar birlikte analiz edildiğinde, ilk trimester inflammatuar belirteçlerinin olumsuz sonuçları istatistiksel anlamlı öngördüğünü gösterdi; ancak, bu belirteçler sigara içen grup içinde öngörü değeri göstermedi.

Sonuç: Sigara içen hamile kadınlarda olumsuz obstetrik sonuçlar, artan YYBU ihtiyacı ve yüksek serum inflammatuar belirteçleri gözlemlendi. Ancak bu markerlar olumsuz sonuçları öngörmeye yetersiz kalmıştır.

Anahtar Kelimeler: Sigara içiciliği, hamilelik, inflammatuar belirteçler, obstetrik komplikasyonlar, NICU

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INTRODUCTION

Smoking, tobacco use, and nicotine addiction continue to cause of morbidity and mortality worldwide, accounting for over 7 million deaths annually (1). As a global public health concern, smoking—especially when initiated at a young age—poses significant risks for pregnancy and neonatal health. Infants born to mothers who smoke are at increased risk for fetal anomalies, low birth weight, placental abruption, and stillbirth, while long-term complications include asthma, obesity, and neurodevelopmental disorders (2). Harmful substances such as nicotine present in cigarette smoke can cross the placenta and adversely affect fetal health through intrauterine exposure (3).

Systemic inflammatory indices can be easily calculated from complete blood count (CBC) parameters and, as shown in previous studies, have been useful in predicting prognosis in conditions such as cancer, diabetes, chronic inflammatory, and autoimmune diseases. In this study, we aimed to investigate obstetric complications in pregnant smokers and evaluate whether first-trimester systemic inflammatory indices could predict adverse obstetric and neonatal outcomes.

MATERIALS AND METHODS

This retrospective observational study included 43 pregnant women aged 18–45 years who had been smoking since the pre-pregnancy period and gave birth at the hospital between 2024 and 2025, along with 44 healthy pregnant women as controls. The study was approved by the Clinical Research Ethics Committee of Uşak University (Ethics No: 715-715-19, Date: 12.06.2025) and was conducted in accordance with the Declaration of Helsinki. Since the data were anonymised and collected retrospectively, a waiver of written informed consent was granted. Exclusion criteria included multiple pregnancy, anemia, hematological disorders, any inflammatory disease, history of cancer, infectious conditions, and fetal chromosomal or structural anomalies.

During the study period, a total of 2,119 deliveries were recorded at our hospital. However, only 43 pregnant women were identified who had first-trimester CBC results available in the hospital information system and who had documented history of smoking from the pre-pregnancy period throughout their entire pregnancy. These women also received antenatal care and delivered at the same hospital. The control group consisted of 44 randomly selected healthy pregnant women with similar demographic characteristics who were recorded in the hospital system as non-smokers (every second eligible patient).

Demographic characteristics of the participants, as well as obstetric outcomes such as birth weight and gestational age at delivery, and neonatal outcomes including APGAR scores, need for neonatal intensive care unit (NICU) admission, and obstetric complications, were evaluated. Adverse obstetric complications were defined as gestational diabetes, hypertensive diseases of pregnancy, preterm birth, fetal growth restriction, and oligohydramnios. From routine first-trimester (1st–14th gestational week) CBC parameters, the following systemic inflammatory markers were calculated: neutrophil-to-lymphocyte ratio (NLR), systemic immune-inflammation index (SII: $\text{NLR} \times \text{platelet count}$), systemic inflammation response index (SIRI: $\text{NLR} \times \text{monocyte count}$), aggregate index of systemic inflammation (AISI: $\text{NLR} \times \text{platelet count} \times \text{monocyte count}$), and platelet-to-lymphocyte ratio (PLR). These markers were analyzed to investigate their predictive value for adverse obstetric and neonatal outcomes.

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). The normality of variables was assessed using both the Shapiro-Wilk and Kolmogorov-Smirnov tests. Variables that met the assumptions of normality were analyzed using parametric tests, whereas variables that violated normality assumptions were analyzed using non-parametric tests. Non-normally distributed data were presented as median and interquartile range (IQR), while categorical variables were summarized as number (n) and percentage (%). For comparisons between two independent groups, the Mann-Whitney U test was used for non-parametric variables, and the independent samples t-test was used for normally distributed variables. A p-value < 0.05 was considered statistically significant.

Receiver Operating Characteristic (ROC) curves were constructed to evaluate the predictive value of systemic inflammatory indices for adverse obstetric and neonatal outcomes. The area under the curve (AUC) values were calculated using standard methods and presented as AUC ROC (95% confidence interval). Optimal cut-off values for the inflammatory indices were determined using the Youden Index. The required sample size was calculated using G*Power, based on SIRI values reported in a previous study; a minimum of 26 participants per group was required to achieve 90% power with a 5% margin of error (4).

RESULTS

Table 1 presents the baseline characteristics of both groups. Although the birth weight of newborns of mothers who smoked was lower, this difference was not statistically significant. The emergency cesarean sections and obstetric complications were

Table 1. Baseline characteristics of participants

	Smoking group (n=43)	Non-smoking group (n=44)	P value
Maternal age (years)	27 (7)	28 (8)	0.189
Pre-gestastational BMI (kg/m ²)	28.6 (8.5)	27.5 (3.9)	0.375
Nulliparity (n, %)	16 (37.2)	20 (45.5)	0.435
Female fetal gender (n, %)	24 (55.8)	23 (52.2)	0.395
Gestational age at birth (week)	38 (3)	38 (1)	0.468
Birth weight (gram)	3000 (483)	3180 (613)	0.872
Emergency cesarean section (n, %)	8 (18.6)	2 (0.04)	0.040
APGAR score at 1st minute	9 (1)	9 (0)	0.681
APGAR score at 5th minute	10 (1)	10 (1)	0.759
NICU admission (n, %)	12 (27.9)	2 (0.04)	<0.001
Adverse perinatal outcomes (n, %)	7 (16.2)	16 (36.3)	0.024

Note: Data are presented as number (%), and median (interquartile range) with 95% confidence intervals for non-parametric data. Groups were compared using the Mann-Whitney U test. P-values < 0.05 were considered statistically significant.
BMI, body mass index; NICU, neonatal intensive care unit

Table 2. First-trimester serum inflammatory parameters in both groups

	Smoking group (n=43)	Non-smoking group (n=44)	P value
WBC (10 ⁹ /L)	10.5 (4.9)	7.8 (2.7)	<0.001
Neutrophil (10 ⁹ /L)	8.1 (4.4)	5.6 (2.4)	<0.001
Lymphocyte (10 ⁹ /L)	1.9 (1)	1.8 (0.9)	0.606
Monocyte (10 ⁹ /L)	0.5 (0.2)	0.4 (0.1)	0.602
Eosinophil (10 ⁹ /L)	0.07 (0.1)	0.1 (0.1)	0.904
Basophils (10 ⁹ /L)	0.02 (0.01)	0.02 (0.02)	0.677
SII	1019.4 (574)	737.7 (565)	0.018
SIRI	2.21 (1.1)	1.13 (1.2)	0.008
AISI	548.4 (341)	305.6 (321)	0.049
NLR	4.1 (1.8)	2.9 (2.3)	0.004
PLR	140.8 (111)	142.6 (67.8)	0.809

Note: Data are presented as number (%), and median (interquartile range) with 95% confidence intervals for non-parametric data. Groups were compared using the Mann-Whitney U test. P-values < 0.05 were considered statistically significant.

AISI, aggregated index of systemic inflammation; NLR, neutrophil-to-lymphocyte ratio; SII, systemic inflammation index; SIRI, systemic inflammatory response index, PLR, platelet-to- lymphocyte ratio

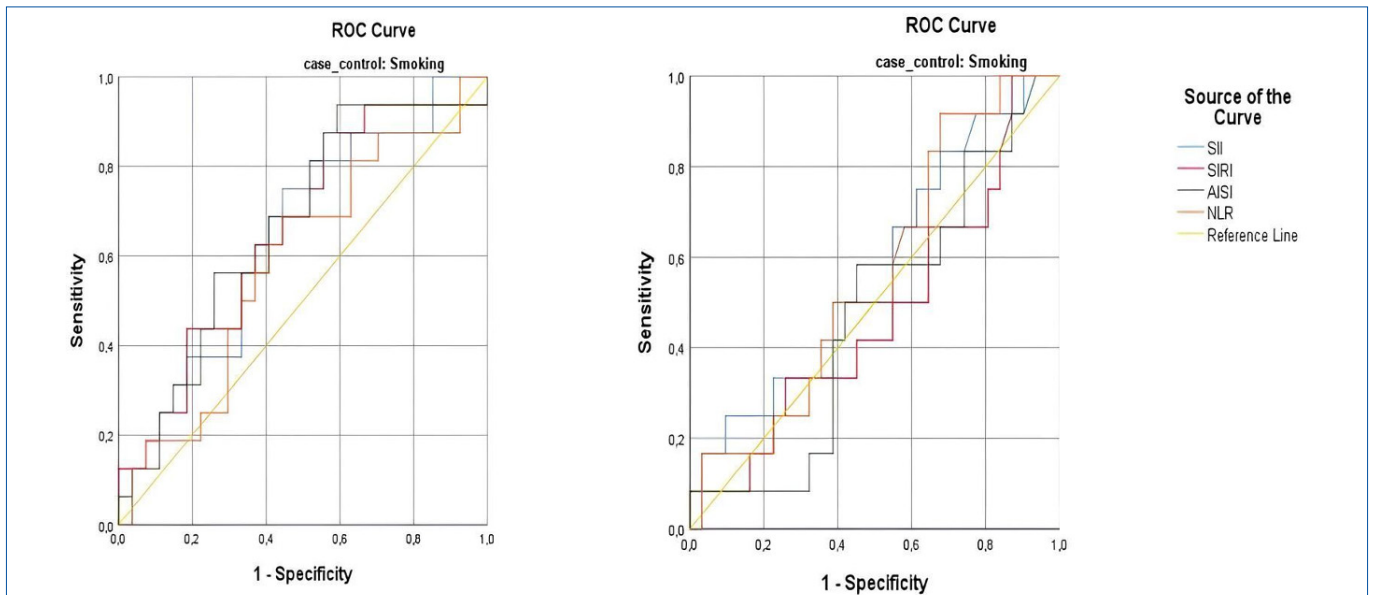
**Figure 1.** ROC analysis of inflammatory markers predicting adverse obstetric outcomes (left) and NICU admission (right) in pregnant smokers

Table 3. The ROC curve analysis for the performance of first trimester inflammatory markers in predicting adverse obstetric outcomes and NICU admission in all participants

Variable	Cut-off	AUC	p value	95% CI	Sensitivity	Specificity
Adverse obstetric						
SII	1007.7	0.730	0.001	0,609-0,850	%69.6	%70.3
SIRI	1.86	0.730	0.001	0,608-0,853	%65.2	%65.6
AISI	502.4	0.736	0.001	0,614-0,859	%65.2	%64.1
NLR	3.82	0.676	0.013	0,547-0,805	%65.2	%65.6
NICU						
SII	976.3	0.722	0.009	0,590-0,853	%71.4	%63
SIRI	1.83	0.688	0.026	0,550-0,827	%71.4	%61.6
AISI	552.5	0.669	0.046	0,528-0,809	%64.3	%69.9
NLR	3.8	0.727	0.007	0,604-0,849	%64.3	%61.6

Note: P-values < 0.05 were considered statistically significant.

AUC, area under the curve; NICU, neonatal intensive care unit ; AISI, aggregated index of systemic inflammation; NLR, neutrophil-to-lymphocyte ratio; SII, systemic inflammation index; SIRI, systemic inflammatory response index

statistically significantly higher in the smoking group. The most common complications among smoking mothers were hypertensive disorders of pregnancy (n=4), preterm labor (n=4), and fetal growth restriction (n=4), whereas the most frequent complication in the healthy group was preterm labor (n=4).

Table 2 displays the serum systemic inflammatory parameters of the study and control groups. Inflammatory markers were significantly higher in the smoking group. Figure 1 illustrates the ROC analysis of SII, SIRI, AISI, and NLR for predicting adverse obstetric outcomes and NICU requirement in the smoking group. Although the inflammatory markers were elevated in the smoking group, they did not maintain statistical significance in predicting adverse obstetric and neonatal outcomes.

Table 3 shows the analysis of all participants' serum inflammatory markers for predicting poor obstetric outcomes and NICU admission. SII, SIRI, AISI, and NLR were found to be statistically significant predictors of adverse outcomes. The optimal cut-off values for the inflammatory indices, determined using the Youden Index, are provided in Table 3.

DISCUSSION

Smoking increases reactive oxygen species and proinflammatory mediators, creating a state of chronic inflammation that may lead to endothelial damage and organ dysfunction. Furthermore, maternal smoking is thought to cause epigenetic alterations in the fetus through DNA methylation and histone modification (5). A meta-analysis revealed that smoking could influence the maternal hypothalamic-pituitary-adrenal (HPA) axis, potentially affecting

fetal programming and elevating cortisol levels during early childhood (6). A previous large-scale study found that smokers had significantly higher levels of cytokines such as IL-6 and TNF, matrix metalloproteinases involved in vascular remodeling, and the systemic inflammatory marker C-reactive protein (7).

Despite its role in low-grade inflammation, the effects of habitual smoking remain controversial. One study found a blunted HPA response in regular smokers subjected to psychosocial stress testing (8), while another reported that chronic nicotine exposure leads to neuroadaptation and desensitization of acetylcholine receptors (9). This phenomenon, referred to as the "smoker's paradox," suggests that the mechanisms by which smoking affects metabolism remain unclear.

In our study, we observed elevated systemic inflammatory parameters in mothers who smoked prior to and during pregnancy. Although inflammatory markers were statistically significant predictors of obstetric complications and NICU admission among all participants, they failed to predict adverse perinatal outcomes specifically within the smoking group. These findings suggest that habitual smoking may mask or suppress the predictive performance of inflammatory markers.

Maternal smoking is a significant risk factor that negatively affects both maternal health and fetal development. The toxic substances in cigarettes can lead to placental dysfunction, reduce uteroplacental blood flow, and cause adverse fetal effects. In our study, consistent with previous findings, smoking was associated with adverse perinatal outcomes such as intrauterine growth restriction, preterm birth, and low birth weight (10).

In this study, an increase in NICU admissions was observed among infants of smoking mothers, while APGAR scores were similar between the groups. A large cohort study conducted in Australia reported a similar rise in NICU admissions among babies of smoking mothers, along with an increased likelihood of maternal hypertension (11). A population-based study from Macedonia also identified smoking as a significant risk factor for fetal growth restriction (12). There are also various studies on smoking and how it affects the APGAR score and NICU requirements. Previous research has shown that neonates of smoking mothers had lower first-minute APGAR scores, but similar fifth-minute APGAR scores and NICU admission rates compared to non-smokers (13, 14).

Additionally, the fact that not all infants born to smoking mothers exhibit growth restriction suggests that epigenetic factors may influence susceptibility to the harmful effects of smoking (5).

One of the earliest studies investigating CBC parameters in smokers was conducted by Winkel et al., which demonstrated that smoking leads to a significant decrease in eosinophil count and a delayed increase in neutrophil count (15). Interestingly, this study also showed that while smoking initially caused an increase followed by a decrease in lymphocyte count, lymphocyte levels during smoking days remained lower than those on non-smoking days. According to a study by Tulgar et al., smokers exhibited increased white blood cell counts, neutrophil counts, and NLR levels (16). In subgroup analyses, a linear correlation was found between NLR and both the average age and pack-year history of the smokers. In another recent study, although heavy smoking men showed increased white blood cell and neutrophil counts, the NLR did not differ significantly between smokers and non-smokers (17).

Systemic inflammatory markers calculated from complete blood count—such as SIRI, SII, NLR, and AISI—have recently been investigated in obstetric practice, particularly for their predictive potential in adverse pregnancy outcomes like preeclampsia, preterm birth, and NICU admission. In a large-scale study evaluating inflammatory markers and preterm labor, first-trimester SIRI, SII, and NLR levels were found to be elevated in the preterm birth group, and these markers retained statistical significance in both univariate and multivariate analyses (18). However, the relationship between these markers and prognosis has yielded variable results in the literature.

In a previous prospective study, first-trimester SII and SIRI levels were found to be elevated in women with gestational diabetes (19). Although these markers were significant in predicting gestational diabetes, they were not sufficient to predict the need for insulin therapy. Another study found that AISI was statistically significant

in predicting gestational diabetes (20). In a study including pregnant women with intrahepatic cholestasis of pregnancy (ICP) inflammatory markers were evaluated across all three trimesters (21). While first-trimester SIRI levels were similar between ICP and healthy groups, SIRI was significantly higher in the ICP group during later trimesters. However, regression analysis showed that this marker was not significant in predicting adverse obstetric outcomes. Another study found that although SII and NLR levels were significantly higher in fetal growth restriction cases, they were not associated with neonatal outcomes (22).

In our study, although serum inflammatory markers were elevated in pregnant smokers, their inability to predict adverse outcomes and need for NICU admission may be related to the limited number of participants. Additionally, the impact of smoking on hematological parameters warrants further clarification through larger-scale studies in the future.

CONCLUSION

It is evident that the low-grade chronic inflammation caused by smoking, along with its harmful constituents, poses significant risks to both maternal and fetal health. In this study, pregnant smokers were found to have higher rates of adverse obstetric outcomes, increased NICU admissions, and elevated serum inflammatory markers. However, these markers proved insufficient in predicting adverse outcomes.

Conflicts of Interest

The authors declare no conflict of interest.

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Authors' Contributions

B.A.A.: Writing, data curation, original draft. E.B.: Data curation, writing – review and editing.

Availability of Data and Materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

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