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## ABSTRACT

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# MATHEMATICAL MODEL FOR PREDICTING THE OCCURRENCE OF PRETERM BIRTH IN WOMEN AT RISK BASED ON THE STUDY OF ESTRADIOL

Preterm birth is one of the most pressing problems in modern obstetric practice, which not only endangers the life and health of newborns but also has serious consequences for women's health. They are defined as labour occurring before the 37th week of pregnancy and can be caused by a variety of factors, including biological and endocrine disorders. One of the important hormones that plays a critical role in maintaining a normal pregnancy is estradiol. Low or abnormal levels of this hormone may indicate the presence of disorders that increase the likelihood of preterm birth.

**The aim of the study** is to develop a mathematical model to determine the probability and percentage of prediction of preterm birth in women at risk based on the study of estradiol.

**Materials and methods:** The study analysed the level of estradiol in 60 women (including 30 at risk of preterm birth and 30 absolutely healthy women) who were in the Chernivtsi Regional Perinatal Centre. Estradiol levels were assessed both before and after treatment. The logistic regression method was used to develop a mathematical model for predicting preterm birth, which allows to estimate the probability of preterm birth based on changes in estradiol levels. The Welch's T-test was used to test the statistical significance of the results, which allows comparing the mean values of hormone levels before and after treatment and assessing the effectiveness of treatment measures.

**Results:** A one-unit increase in estradiol increased the odds of preterm birth by 0.985 times (decreased the odds of preterm birth by 1.5%).

**Conclusions:** The mathematical logistic regression model based on estradiol levels demonstrated an inverse relationship between estradiol levels and the probability of preterm birth, which allows predicting risk based on changes in the concentration of this hormone. An increase in estradiol levels by one unit reduces the likelihood of preterm birth by

1.5%, which opens up new opportunities to improve the prediction and management of pregnancy in women at risk.

**Key words:** preterm birth, pregnancy, hormones, placenta, children, mathematical model, estradiol, placental dysfunction, prediction.

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**МАТЕМАТИЧНА МОДЕЛЬ ПРОГНОЗУВАННЯ ВИНИКНЕННЯ ПЕРЕДЧАСНИХ ПОЛОГІВ У ЖІНОК ГРУПИ РИЗИКУ НА ОСНОВІ ВИВЧЕННЯ ЕСТРАДІОЛУ**

Передчасні пологи є однією з найбільш актуальних проблем сучасної акушерської практики, що не тільки ставить під загрозу життя та здоров'я новонароджених, але й має серйозні наслідки для здоров'я жінки. Вони визначаються як пологи, що наступають до 37-го тижня вагітності, і можуть бути спричинені різноманітними чинниками, серед яких особливе місце займають біологічні та ендокринні порушення. Одним із важливих гормонів, що відіграє критичну роль у підтриманні нормального перебігу вагітності, є естрадіол. Низький або аномальний рівень цього гормону може вказувати на наявність порушень, що підвищують ймовірність виникнення передчасних пологів.

**Мета дослідження** — розроблення математичної моделі для визначення ймовірності та відсотка прогнозування виникнення передчасних пологів у жінок групи ризику на основі вивчення естрадіолу.

**Матеріали та методи:** У дослідженні було проаналізовано рівень естрадіолу у 60 жінок (з них: 30 з ризиком виникнення передчасних пологів та 30 абсолютно здорових), які перебували в КНП "Чернівецький обласний перинатальний центр". Оцінювали рівень гормону естрадіолу як до початку лікування, так і після лікування. Для розробки математичної моделі прогнозування передчасних пологів був використаний метод логістичної регресії, що дозволяє оцінити ймовірність виникнення передчасних пологів на основі змін рівня естрадіолу. Для перевірки статистичної значущості отриманих результатів застосовували Т-критерій Велча, що дозволяє порівняти середні значення рівнів гормону до та після лікування та оцінити ефективність лікувальних заходів.

**Результати:** Збільшення естрадіола на одну одиницю збільшить шанси передчасних пологів у 0,985 рази (зменшить шанси передчасних пологів на 1,5%).

**Висновки:** Побудована на основі рівня естрадіолу математична модель логістичної регресії продемонструвала зворотний зв'язок між рівнем естрадіолу та ймовірністю виникнення передчасних пологів, що дозволяє прогнозувати ризик на підставі змін концентрації цього гормону. Збільшення рівня естрадіолу на одну одиницю знижує ймовірність передчасних пологів на 1,5%, що відкриває нові можливості для покращення прогнозування та управління вагітністю у жінок групи ризику.

**Ключові слова:** передчасні пологи, вагітність, гормони, плацента, діти, математична модель, естрадіол, плацентарна дисфункція, прогнозування.

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## INTRODUCTION / ВСТУП

Preterm birth is one of the most pressing problems of modern obstetric practice, which not only endangers the life and health of newborns but also has serious consequences for women's health. They are defined as labour occurring before the 37th week of pregnancy and can be caused by a variety of factors, including biological and endocrine disorders [5, 11]. One of the most important hormones that plays a critical role in maintaining a normal pregnancy is estradiol. Low or abnormal levels of this hormone may indicate the presence of disorders that increase the likelihood of preterm birth [1, 2].

In recent decades, attention has increased significantly to the use of mathematical models in obstetrics, in particular for predicting and early detection of preterm birth risks [10, 19]. This is due to the need to develop accurate and reliable tools that minimise the human factor, reduce the number of diagnostic errors, and take the necessary measures to prevent preterm birth in a timely manner [7,14]. Mathematical models based on the analysis of estradiol data in the blood of pregnant women can be a powerful tool for predicting the risk of preterm birth, allowing obstetricians and gynaecologists to make informed decisions based on scientific data [3, 4].

The idea of creating mathematical models for predicting preterm birth based on hormonal parameters, in particular estradiol, is to study the patterns of its level during pregnancy [16, 18]. Since estradiol levels clearly depend on the stage of pregnancy and can also change under the influence of various pathological processes, the development of mathematical models based on such data can significantly improve the accuracy of prediction [6]. Using modern mathematical modelling methods, including statistical and algorithmic approaches, it is possible to create tools that allow for early detection of potential risks for women at risk [8].

Modelling the processes associated with estradiol and preterm birth not only provides prognostic data, but also contributes to a better understanding of the mechanisms underlying these processes [15, 17]. Mathematical models can include a variety of factors, such as a woman's age, comorbidities, hormonal levels, previous pregnancies and births, and other medical indicators that allow for an accurate risk assessment [9, 12].

The use of mathematical models to predict preterm birth based on estradiol helps to more accurately identify risk groups and provide timely prevention and treatment, which helps to reduce the rate of preterm birth and improve outcomes for the mother and newborn [13, 20].

**The aim of the study** is to develop a mathematical model for determining the probability and percentage of prediction of preterm birth in women at risk based on the study of estradiol.

## MATERIALS AND METHODS

The study analysed estradiol levels in 60 women (including 30 at risk of preterm birth and 30 absolutely healthy women) who were in the Chernivtsi Regional Perinatal Centre. Estradiol levels were assessed both before and after treatment. The logistic regression method was used to develop a mathematical model for predicting preterm birth, which allows to estimate the probability of preterm birth based on changes in estradiol levels. To test the statistical significance of the results, the Welch's T-test was used to compare the mean values of hormone levels before and after treatment and to assess the effectiveness of treatment measures.

## RESULTS AND DISCUSSION

The mean estradiol value in the intervention group was 27.073 (SD = 7.212), and the mean estradiol value in the control group was 66.68 (SD = 16.348). The Welch's t-test for the two samples showed that there was a statistically significant difference ($t(39.876) = 12.141$, $p < 0.0001$) (Fig. 1).

The mean estradiol value in the preterm delivery subgroup was 29.914 (SD = 5.849), and the mean estradiol value in the term delivery subgroup was 26.209 (SD = 7.476). The Welch's t-test for the two samples did not show that the difference was statistically significant ($t(12.6) = -1.370$, $p = 0.195$) (Fig. 2).

The mean estradiol value in the preterm delivery subgroup was 71.669 (SD = 13.843), and the mean estradiol value in the term delivery subgroup was 63.075 (SD = 17.652). The Welch's t-test for the two samples did not show that the difference was statistically significant ($t(12.569) = -1.343$, $p = 0.203$) (Fig. 3).

A logistic regression was built on the basis of estradiol to predict the probability of preterm birth.

The model for predicting the probability of preterm birth based on estradiol is as follows:

$$p = \frac{e^{-0.015 \cdot x}}{1 + e^{-0.015 \cdot x}}$$

$x$ – the value of estradiol

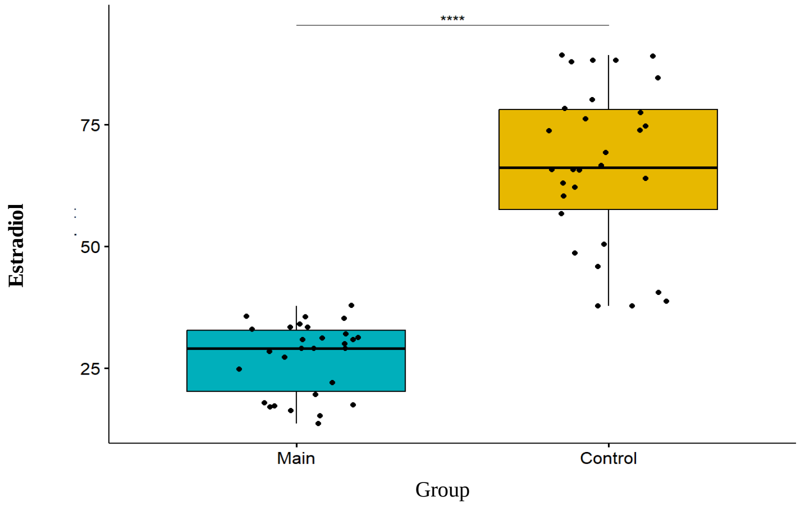


Figure 1 – Mean estradiol values (before treatment) in the treatment and control groups

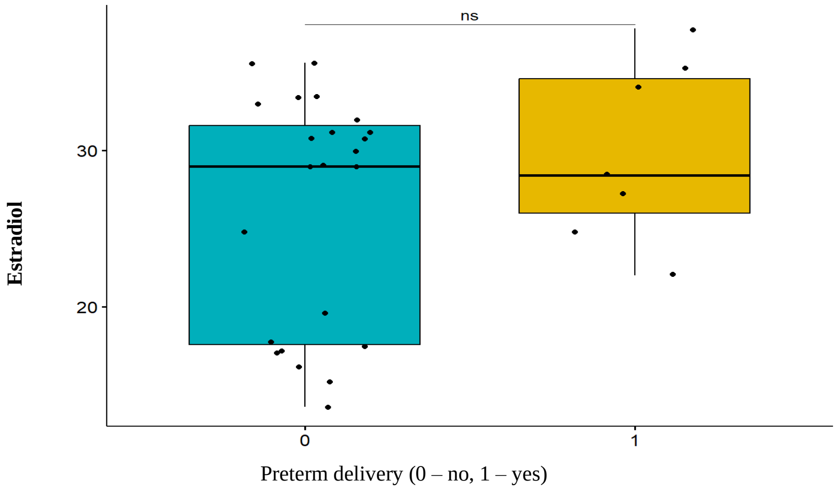


Figure 2 – Mean estradiol values (before treatment) in the main group in relation to preterm delivery

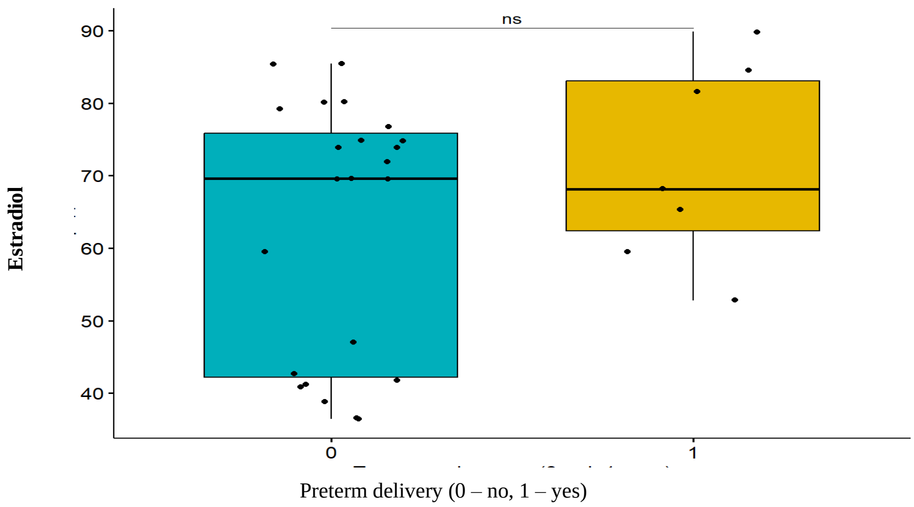


Figure 3 – Mean estradiol values (after treatment) in the main group in relation to preterm delivery

The coefficient around the variable is negative and amounts to b=-0.015. This means that an increase in estradiol will be associated with a decrease in the likelihood of preterm birth.

A one-unit increase in estradiol would increase the odds of preterm birth by 0/985 times (reduce the odds of preterm birth by 1.5%).

**CONCLUSIONS**

The mathematical model of logistic regression based on estradiol levels demonstrated an inverse relationship between estradiol levels and the probability of preterm birth, which allows predicting risk based on changes in the concentration of this hormone. A one-unit increase in estradiol levels reduces the likelihood of preterm birth by 1.5%, which opens up new opportunities to improve pregnancy prediction and management in high-risk women.

## PROSPECTS FOR FUTURE RESEARCH / ПЕРСПЕКТИВИ ПОДАЛЬШИХ ДОСЛІДЖЕНЬ

Further research should include expanding the sample of women studied to ensure greater accuracy of results and statistical significance. It is also important to study the impact of other biochemical parameters, such as progesterone, cortisol and other hormones, on the likelihood of preterm birth, which would allow for more comprehensive prediction models. In addition, improving mathematical models using machine learning techniques can significantly improve the accuracy and efficiency of forecasting. Long-term follow-up of treatment outcomes will help evaluate the effectiveness of different approaches to correcting estradiol levels and their impact on the risk of preterm birth.

## AUTHOR CONTRIBUTIONS / ВКЛАД АВТОРІВ

The author confirms sole responsibility for the following: conception and design of the study, data collection, analysis and interpretation of the results, and preparation of the manuscript.

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None.

## CONFLICT OF INTEREST / КОНФЛІКТ ІНТЕРЕСІВ

The authors declare no conflict of interest.

## ARTIFICIAL INTELLIGENCE DISCLOSURE / ВИКОРИСТАННЯ ШТУЧНОГО ІНТЕЛЕКТУ

The authors confirm that no artificial intelligence-based technologies were utilized in the writing or editing of the manuscript.

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