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PRETERM BIRTH PREDICTION: THE ROLE OF GENETIC, CLINICAL, AND ENVIRONMENTAL FACTORS IN HIGH-RISK PREGNANCIES

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АННОТАЦИЯ

Preterm birth continues to be one of the roughest problems in obstetrics with determining effects on maternal and neonatal health. This thesis is based on the labeling and forecasting of preterm labor risk in mothers and fetal interventions, to enhance early detection and intervention of preterm labor. Multiple determinants, including maternal background, age, history of delivery of preterm and other pregnancy outcomes, lifestyle choices, as well as others, play a role in increased risk of preterm birth. This research explores traditional clinical indicators and emerging technologies such as genetic screening, biomarkers, and advanced imaging to develop more accurate prediction models. Using the interaction of these risk factors, the study aims to offer a more holistic way to estimate the risk of preterm birth. In this study, research aims to improve clinical outcomes by developing earlier detection of high-risk pregnancies and offering customized care plans that decrease complications and improve maternal and neonatal health.

КЛЮЧЕВЫЕ СЛОВА

Preterm birth, Prediction models, Genetic markers, Maternal health, Risk factors, Lifestyle factors, and Prenatal care.

АКТУАЛЬНОСТЬ

Preterm birth, delivery before 37 weeks of gestation, continues to be the most common cause of maternal and perinatal morbidity and mortality globally. However, predicting and controlling preterm birth remains a major challenge toward advancements in obstetrics. Pregnant women face varying levels of risk for preterm labor, influenced by factors such as previous preterm births, medical conditions like hypertension and diabetes, maternal age, and lifestyle choices such as

smoking and poor nutrition. Knowledge of these risk factors and the ability to predict preterm birth is crucial to making progress in achieving better results for both the mothers and their infants. Precise prediction of preterm pregnancies is critical to time intervention that can further the decreasing of adverse events and unnecessary health risks. Yet, current prediction models frequently fail to deliver consistent, reliable predictions because of the intricate interaction of risk factors. This study attempts to investigate more sophisticated prediction techniques using multiple sources of information, such as clinical assessment, genetic factors, etc., to better estimate the risk of preterm labor.

Preterm birth [before 37 weeks gestation], is still a cause of maternal and neonatal morbidity and mortality across the world. Despite considerable developments in the field of obstetrics, the prediction of preterm birth remains a challenge because of its multifactorial origin. Maternal factors, previous preterm deliveries, infection, and age have long been known to be important contributing risk factors for preterm delivery. Women who have previously delivered preterm babies are at an increased risk in subsequent pregnancies, emphasizing the importance of assessing obstetric history. Apart from medical factors, lifestyle factors including smoking, stress, and unhealthy nutrition also play a role in preterm birth risk and thus, highlight the role of behavioral and biological factors. Research has revealed that some socioeconomic determinants, including lack of access to health care and poverty, even strengthen this risk. Recent research has also brought attention to the role of genetic factors in preterm birth. Recent findings indicate that preterm birth potentially is influenced by genetic predisposition and that part of the mothers carries genetic variants resulting in an increased risk of preterm labor. Although genetic testing for prenatal care is still under development, genetic studies found mutations in genes related to the inflammatory process, cervical insufficiency, and immune function, which could contribute to the development of preterm birth. This suggests an opportunity for genetic screening to be integrated into clinical practice as a means of more effectively identifying at-risk pregnancies. Yet, incorporating genomic data into the current clinical models is still nontrivial. Classic prediction models of preterm birth have been built based on clinical, maternal factors, including maternal age, cervical shortens, and a history of preterm labor. While these models have provided valuable insights, they remain limited in their accuracy. Current studies aim at integrating clinical, genetic, and environmental data into increasingly powerful and personalized prediction models. Although such attempts have been made, no single model has gained the status of general effectiveness, pointing to the need for continuous updates in predictive approaches.

Initially, clinical information is collected using routine prenatal care visits, including maternal medical history, maternal age, previous pregnancy outcomes, and psychosocial factors such as smoking and diet. Second, genetic information is derived from blood samples in an attempt to find genetic markers that are associated with an increased risk of preterm delivery in women. This step acknowledges the growing body of research suggesting a genetic basis for preterm labor, which may not always be evident through clinical indicators alone. Data analysis will embrace both statistical approaches and machine learning approaches. Traditional statistical analysis (e.g., logistic regression) will be used to extract the most relevant predictors for preterm birth, and machine learning techniques (e.g., decision tree learner and random forest classifier) will be used to incorporate those complex interactions among the variables. This methodological strategy is built to enable the detection of both linear and non-linear associations between clinical, genetic, and environmental factors and will offer a better finely detailed view of factors that contribute to preterm birth. In addition, ethical aspects will be of great concern for the entire research. Informed consent will be secured from all participants, such that they are well informed about what the study

is for and how data will be used. This study aims to contribute to the further development of more precise, complete, and differentiated predictive models that can enhance the early identification and prevention of threatened pregnancies. The analysis of data collected from a cohort of pregnant women reveals significant insights into the multifactorial nature of preterm birth prediction. In the study, the authors validated that the standard clinical covariates (maternal age and history of a previous preterm birth) continue to be prognostic of preterm labor. Women with a history of preterm deliveries were found to be at a substantially higher risk of experiencing preterm birth in subsequent pregnancies. This result is consistent with previous work and strengthens the relevance of obstetric history in the identification of preterm labor. Furthermore, genetic screening revealed various genetic markers that are linked to a higher risk of preterm birth. These markers, mainly associated with immune response and inflammation, indicate a biological tendency to preterm labor. Even if genetic screening is not yet a standard part of prenatal care, the findings of this study endorse the hypothesis that genetic factors have a decisive influence on preterm birth, contributing another dimension to the predictive process. Environmental factors, including lifestyle choices such as smoking, diet, and stress levels, were also found to influence the risk of preterm birth. Data indicated a high level of association between stress and smoking with a higher risk of preterm birth. This also points to the need to include environmental factors in predictive models as modifiable risk factors that may be targeted by intervention. When these factors were integrated into a comprehensive predictive model, the accuracy of preterm birth predictions improved significantly compared to traditional models that rely solely on clinical factors. Clinical assessment, genetic markers, and environmental factors combined have resulted in an increasingly robust model with improved sensitivity and specificity. This highlights the possible advantages of a multifactorial prediction for preterm delivery and superior personalization of risk stratification in preterm labor.

The findings of this work highlight the complex aspect of preterm birth and the demand for a holistic method to predict its occurrence. This study demonstrated that a multifactorial model is more discriminatory than single clinical prediction techniques, using a combination of clinical, genetic, and environmental data. Maternal history, specifically prior preterm birth, continues to be a major predictor, consonant with the current literature. Nevertheless, this work additionally reveals the substantial contribution of genetic factors in preterm delivery, bringing a new layer to explain its etiologies. The presence of genetic factors associated with inflammation and immune response implies that preterm birth may have a hidden biological principle, which is not easily determined from clinical characteristics alone. This is consistent with the possibility that genetic screening may eventually be a routine component of prenatal care, even for women who have no history of preterm birth but have a genetic risk factor. Furthermore, the identification of environmental factors, such as stress and smoking, reinforces the idea that lifestyle modifications can play a significant role in reducing the risk of preterm labor. All of these findings align with previous work supporting a more integrative prediction of preterm birth. Although useful, conventional clinical models tend to underestimate the ability to predict preterm labor. Healthcare professionals can use genetic and environmental data to provide more individualized care plans that can lead to better outcomes for mothers and infants. Despite the promising results, this study does have limitations.

Conclusion

This study highlights the multifactorial origin of preterm birth, showing that reliable prediction comes from the combination of clinical, genetic, and environmental factors. Although maternal history including history of preterm delivery is a major predictor, the incorporation of

genetic markers and stress and smoking can substantially improve predictive ability. The identification of genetic markers of immune response and inflammation that are specific can open new perspectives for early diagnosis and can be used as potential markers by genetic screening in prenatal medicine. Nonetheless, current studies should consider some limitations of sample size and the dynamic characteristics of genetic testing in future studies. The need for larger, more homogenous cohorts and additional validation of the genetic and biomarker-based models is evident [1,2]. In this work, the paper also helps to build a more individualized and contributing strategy to preterm birth prediction and helps to improve mothers' and infants' outcomes.

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