Predicting and Relation between Bio-psychosocial Factors and Type of Childbirth using Decision Tree Method

Saiedeh sadat Hajimirzaie
Shahrood University of Medical Sciences
Najmeh Tehranian
Tarbiat Modares University Faculty of Medical Sciences
Seyed Abbas Mousavi
Mazandaran University of Medical Sciences
Amin Golabpour
Shahrood University of Medical Sciences
Mehdi Mirzaii
Shahrood University of Medical Sciences
Afsaneh Keramat
Shahrood University of Medical Sciences
Ahmad Khosravi (khosravi2000us@yahoo.com)
Shahrood University of Medical Sciences

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Abstract

Background

Growing the worldwide and Iranian cesarean section rate and rising morbidity and mortality thereafter for the mother and infant has been an important health issue. Predictive models can identify individuals with a higher probability of cesarean section and make better decisions. In this study, we investigated the bio-psychosocial factors associated with type of delivery. We designed a predictive model using the decision tree C4.5 algorithm.

Methods

In this longitudinal study 170 pregnant women were sampled in the third trimester of pregnancy. At the baseline phase blood samples were taken from mothers to measure estrogen hormone. Birth information was recorded at the follow-up time at 30–42 days postpartum. Modeling was performed using MATLAB software and C4.5 decision tree algorithm using input variables and the target variable.

Results

Previous type of childbirth, maternal body mass index at childbirth, maternal age, and serum estrogen were the most significant factors in predicting the childbirth type, respectively and decision tree model with 89.6%accuracy in the training stage and 83.3% in the test stage predicted the result.

Conclusion

The decision tree model designed with high accuracy and sensitivity can predict the type of childbirth. By recognizing the contributing factors and model rules, health practitioners and policymakers can take preventive action.

Background

Childbirth is a multidimensional process and a crucial experience in the life of a mother and is a unique experience while being global (1). With advancements in medical science, interventions during childbirth have increased (2), with the cesarean section growing worldwide, and this number is three times higher in Iran according to WHO statistics (3). In certain instances, the form of childbirth is determined by ignorance, misconceptions, behaviors and attitudes, not by the medical indications (4). Psychological factors such as fear and stress can intensify labor pain, and it can be moderated by social support and self-efficacy. Findings suggest that mental health prior to pregnancy or mental health problems during pregnancy is linked with higher cesarean rates. It has also been seen that higher maternal socio-economic status and supplemental health insurance have improved the cesarean Sect. (5). Biological

factors such as known hormones which contribute to labor progression (e.g., oxytocin and cortisol) are also linked with psychological phenomena and may be involved in labor abnormality (1, 5). Therefore, complex biological, psychological and social factors influence the type of childbirth, which can be clarified by the bio-psychosocial model. In this model, a holistic and integrated approach to human and disease behavior is proposed, based on which, each of the three bio-psychosocial components affects and is affected by others. The classification method, which is a kind of data mining, can be designed by identifying the relationships between different biological-psychosocial variables. Classification is the process of finding a model that can identify unknown categories of other objects by identifying categories of data or data concepts. One of the common methods of classification is Decision Tree. The decision tree is created by the (if-then) rules for classification. In the decision tree construction, several algorithms are used, including ID3, C4.5, CHAID and CART, the most important of which is the C4.5 algorithm (6). Given the increasing rate of cesarean section in Iran and the increase in morbidity and mortality thereafter and the effect of type of childbirth on different aspects of quality of life and health and limited studies in Iran in predicting type of childbirth and since knowing the causes of the cesarean section can be a step to reduce it, we decided to use the bio-psychosocial model to investigate the related factors and by identifying these factors; design a model to predict the type of childbirth using the C4.5 algorithm.

Methods

The present study was designed to predict type of childbirth using input variables to the Decision Tree model. This longitudinal study was conducted on 170 pregnant mothers with inclusion criteria were referred to Shahroud Health Care Centers for pregnancy care during the third trimester of pregnancy from 2018 to 2019. Inclusion criteria were: Iranian citizenship, single pregnancy, having electronic records in the health system, no history of illness and no onset of labor pain. A questionnaire including demographic and socio-economic variables, pregnancy history and WHO-5 well-being index were completed.

Measurements:

1- WHO-5 well-being index

The WHO-5 questionnaire consists of five questions about the feelings of the participant during the previous two weeks, with each item being scored on a 6-points Likert scale of 0– 5. Raw ratings are converted onto a scale from zero to 100. The validity and reliability of Persian version of this scale was assessed in the Iranian population (7). The validity of the WHO-5 questionnaire on pregnant mothers up to 8 weeks postpartum was assessed in a study, the Cronbach's alpha coefficient for the WHO-5 items was 0.85 and a score of 50 or less with a good sensitivity of 84% and a specificity of 59% for psychological symptoms identification used (8). A 2015 review identified WHO-5 as a valid tool for screening for depression (9).

2- Socio-economic index

The socio-economic status was constructed using Principal component analysis (PCA) with combining 3 main factors including economic indicators (occupation, spouse occupation, homeownership status, a separate bedroom for couples, number of bedrooms, indoor bathroom, cooking area), asset-index (including refrigerator, freezer, Color TV, washing machine, dishwasher, microwave, vacuum cleaner, personal car, landline, mobile phone, computer or laptop, internet access) and social factors (education, spouse education, family members, family supplementary health insurance). Finally, 15 variables were used in constructing socioeconomic status variables, which explained 17% of the total variance in this new variable. After calculating a variable called socioeconomic status, based on the twenty-fifth and seventy-fifth percentiles of these variables, the population was grouped into three socio-economic groups with high (41 persons), medium (84 persons) and low (38 persons).

The height and weight of the mothers and attendance in childbirth preparation classes was recorded and then 3^{cc} blood samples were taken from non-fasting antecubital vein (often 9 am to 11 am) to measure estrogen hormone. The blood samples were transferred to the laboratory immediately and centrifuged by the laboratory officer and, before analysis; the samples were frozen at -80 ° C after plasma separation. Serum estradiol E2 levels were assayed by enzyme-linked immunosorbent assay (ELISA) method (Monobind kit, China).

It should be noted that in coordination with mothers during pregnancy and Estimated Date of Confinement (EDC) estimates indicating the probable date of childbirth, we were informed of the time of delivery and childbirth information was recorded at the time of referral to the health centers at 30–42 days postpartum. It should be noted that for 4 of the samples due to emigration from Shahroud and 10 of them due to non-cooperation, the required information was obtained by telephone from 11 of them and finally, 163 samples were analyzed (Fig. 1). Participants' blood samples examined at the end of the second stage and after ensuring that the type of childbirth data was collected, Serum estradiol E2 levels were assayed by ELISA method (Monobind kit, China).

Data analysis

The data were analyzed with SPSS-21 and MATLAB softwares. Chi-square and t-test were used for initial comparisons between the two groups. P-value < 0.05 was considered as the significant level. A C4.5 decision tree algorithm was developed by using input variables and the determination of the target variable.

The Input Variables including

maternal age, family socioeconomic status, previous type of childbirth, maternal mental health status during pregnancy, maternal birth body mass index (BMI) and maternal serum estradiol E2.

The Output Variables including

Type of childbirth (Vaginal delivery and cesarean section were coded 0 and 1, respectively)

Design of model

At this point, the data is divided into training and testing datasets using the 70 – 30% method, 70% of which is the training data and 30% of the data is considered as the test dataset. The decision tree algorithm is implemented and formed on the training data. The decision tree is then evaluated by training and test dataset. Figure 2 shows the structure of the prediction algorithm.

Results

The mean age of the study population was 28.0 ± 5.7 years and the mean age of the spouses were 32.9 ± 7.0 years. Almost 59% of the sample and 65% of their spouses had a high school diploma or lower. Majority (84%) of women was housewives and 24% of spouses were employed. Nulliparous mothers accounted for 44% of the total samples; 41% were primiparous and 15% multiparous. Only 27% of mothers attended childbirth preparation classes. Deliver type of half of them (48.5%) was cesarean section (35.5% non-emergency and 13% emergency). The causes of the emergency cesarean were: tachycardia, uterine malformations, breech presentation (each of them 5.6%), cephalopelvic disproportion (cpd) (11.1%), non-response to induction (22.2%) and meconium-stained amniotic fluid (MSAF) (50.0%). In this study, 34 repeated second cesarean sections were performed non-emergency and we had no cases of vaginal delivery after cesarean (VBACK); in other words, 100% of cesarean sections were performed cesarean without trying labor. As can be seen in Tables 1, the mean and standard deviation of variables such as age, previous type of childbirth and maternal mental health status in pregnancy were significantly different between the two groups, but socioeconomic status, serum estradiol level and maternal BMI at childbirth were not significantly different.

Table 1
comparison of demographic and socio-economic variables between two groups of delivery types.

Quantitative variable	Total	VD[1]	CS[2]	P-Value (t-test/ Chi-Square)
Age	28.0 ± 5.7	27.9 ± 5.9	30.3 ± 5.3	0.007*
BMI at Birth	30.5 ± 5.4	29.8 ± 4.2	30.7 ± 3.9	0.15
estradiol E2 (pg/ml)	3407.0 ± 1388.0	3481.0 ± 1352.9	3328.3 ± 1430.8	0.48
Socioeconomic status index (%)				0.6
Low	25.2	25.0	25.3	
medium	50.3	53.6	46.8	
High	24.5	21.4	27.8	
Previous childbirth type				0.001*
None	43.6	51.2	35.4	
VD	27.6	48.8	5.1	
CS	27.6	0	57.0	
VD & CS	1.2	0	2.5	
Maternal mental health status				0.04*
=<50	16.0	10.7	21.5	
> 50	84.0	89.3	78.5	
Vaginal Delivery [2] Cesarean Section				

building the model:

1. Training phase:

In this phase, 70% out of 163 samples were used to train the model. With the help of training data, the decision tree was formed based on the entropy and the decision tree was created. The sensitivity and specificity of the model were 85.5% and 94.3%, respectively (Table 2). (However, the accuracy of these measures should be tested in the testing phase.)

Table 2
The output of Tree Algorithm for Training and Test Datasets

Training Datasets							
Confusion Matrix		**Sensitivity**	**Specificity**	**Accuracy**	**PPV**	**NPV**	**F_measure**
53	9	85.5%	94.3%	89.6%	94.6%	84.8%	89.8%
3	50						

In a decision tree the most important information is the set of rules, which consists of a number of logical implications (if-then rule). Figure 3 and Table 3 presents the set of rules created by the C5 model.

Table 3
Association rules

Sr. No.	**Rule**	**Confidence**
1	Previous childbirth type = 2 = > 1, Previous childbirth type = 1 = > 0	95.65
2	(Previous childbirth type = 0 and BMI at Birth < 23.4013) = > 0	66.67%
3	(Previous childbirth type = 0 and BMI at Birth ≥ 24.5577 and age < 20.5) = > 0	91.67%
4	(Previous childbirth type = 0 and BMI at Birth ≥ 24.5577 and age ≥ 20.5 and Estradiol E2 ≥ 4702) = > 0	88.89%
5	(Previous childbirth type = 0 and BMI at Birth ≥ 24.5577 and age ≥ 20.5 and 3987 ≤ Estradiol E2 < 4702) = > 1	81.82%
6	(Previous childbirth type = 0 and BMI at Birth ≥ 24.5577 and age ≥ 20.5 and Estradiol E2 < 1097.1) = > 1	66.67%
7	(Previous childbirth type = 0 and 24.5577 ≤ BMI at Birth < 33.1468 and age ≥ 20.5 and 1097.1 ≤ Estradiol E2 < 3987) = > 0	68.42%
8	(Previous childbirth type = 0 and BMI at Birth ≥ 33.1468 and age ≥ 20.5 and 1097.1 ≤ Estradiol E2 < 3987) = > 1	71.43%

2. Evaluation:

48 samples were used for testing. The data were used to predict by decision tree rules. Table 4 shows the output of the model testing phase compared to the actual results. The sensitivity and specificity of the model were 82.3% and 83.9%, respectively. The results showed that of the 48 training samples used in the test phase, 31 were in the vaginal delivery group and 17 were cesarean, but the decision tree identified 26

cases as vaginal and 14 cases as cesarean section. This means that the model identified 5 people in the vaginal group by cesarean section and three in the vaginal group by mistake.

Table 4
The output of Tree Algorithm for Training and Test Datasets

Testing Datasets							
Confusion Matrix		**Sensitivity**	**Specificity**	**Accuracy**	**PPV**	**NPV**	**F_measure**
14	3	82.4%	83.9%	83.3%	73.7%	89.7%	77.8%
5	26						

Discussion

The purpose of this study was to predict type of childbirth using decision tree model and its derived rules to reduce cesarean section rate. Given the specific variables of a pregnant mother, the probability of cesarean section is estimated based on the obtained rules. In this study, Previous type of childbirth, Maternal BMI at childbirth, maternal age, and serum estrogen were the most significant variables in predicting the childbirth type, respectively, and the decision tree model had predicted the type of childbirth by 89.6% accuracy in training phase and 83.3% in test phase. Studies show that maternal age, especially at first birth, is an important factor affecting cesarean (5, 10–12). Studies have also suggested that obesity is one of the contributing factors (11). Prior studies indicate that obesity led to a two to threefold increase in the risk of emergency cesarean in primiparous and multiparous women (13). Labor abnormality and increased cesarean are also associated with estrogen hormone. In pregnancy, the placenta is the major source of estrogen secretion and as estrogen increases, the estrogen concentration increases and creates a hyperestrogenic state. Estrogens induce myometrial changes including increased production of prostaglandin (PG) E2 and PG F2α by expression of PG receptor enhancer, increased expression of oxytocin receptor, an adrenergic agonist modulating membrane calcium channels, increased connexin synthesis and gap junction formation in myometrium, responsible enzyme regulation of Muscle contraction, such as light chain kinase myosin and calmodulin, which, with all these changes, results in synchronous uterine contractions (14). Regarding the foregoing and considering the known risk factors of the cesarean section such as old age, overweight, history of cesarean section and failure to perform VBAC, the rules were reviewed by the authors of the article and the rules which were clinically valid and scientifically available, presented as final rules. Some of the most important rules that have been approved are:

I. The type of previous mother's childbirth can predict the next childbirth's type with 95.6% probability.
II. Nulliparous mother with a BMI of less than 23.4 gives a vaginal delivery with a probability of 66.7%.
III. Nulliparous mother with ≥ 20.5 years old, BMI ≥ 24.5 at childbirth time, and estradiol E2 ≥ 4702 pg / ml will have a vaginal delivery with a probability of 88.9% .

IV. Nulliparous Mother with ≥ 20.5 years old, BMI ≥ 24.5 at childbirth time, and estradiol E2 levels below 1097.1 pg / ml will have a cesarean section with a probability of 66.7%.

In a study age, height, neonatal weight, high blood pressure, sugar, thyroid, toxemia, breech presentation, sleep disturbance, and multiple pregnancies were predictive factors of childbirth and the decision tree with an accuracy of 100% and 99.5 with predicts the outcome in training and testing datasets (5). Further study indicated 50 factors related to the type of childbirth in 4 groups, used prenatal, during pregnancy, medical and social factors to predict the type of childbirth, the most predictive factor of cesarean section was medical factors, and the decision tree model and artificial intelligence classified 80% and 82% of the results of childbirth, respectively (15). Although, Other models have been used to predict childbirth. Factors affecting maternal vaginal delivery in another study were age of mother (20–25 years old), multiparity, unscarred uterus, rhesus positivity, expected baby weight of 2.5–3.5 kg, cephalic presentation, Bishop status > 4, spontaneous onset of labor, clear liquor and no FHR abnormality. The cut-off score predicted 21 vaginal deliveries with the sensitivity of 80%, the specificity of 65%, the positive predictive value of 70%, and negative predictive value of 76%, respectively, but a score above 21 did not always mean cesarean Sect. (16).

Conclusion

Data mining techniques can be used in health care system by developing appropriate models to predict the likelihood of the occurrence or disease. In this study, data collected from pregnant mothers, including estrogen hormone, were analyzed and a high-precision model was designed using C5 algorithm. This review is the first study to evaluate estrogen hormone as a predictor of the type of childbirth. It is recommended that to implement this model with larger sample size and after reaching the desired accuracy level, to be used in order to reduce the rate of cesarean section in screening programs. By identifying the contributing factors and the rules derived from the model, health practitioners and policymakers can take preventive measures.

Abbreviations

VD
Vaginal Delivery
CS
Cesarean Section
BMI
Body Mass Index

Declarations

Ethics approval and consent to participate

The protocol of this stud was reviewed and approved by the Institutional Review Board of Shahroud University of Medical Sciences [ethical code IR.SHMU.REC.1397.84]. The aims and Necessary explanations of the study were explained to all participants and an informed

written agreement was obtained from them.

Consent for publication

Not applicable.

Availability of data and materials

Data supporting our findings can be sent upon request.

Competing interests

The authors declared that they have no conflict of interests.

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design of the study, collection, analysis, interpretation of data and writing the manuscript.

Authors' contribution

SS.H., SA.M. and N.T. conceived of the presented idea.

SS.H. and A.KH developed the theory and performed the computations.

SS.H. contributed to sample preparation.

SS.H., M.M. and N.T. conceived and planned the experiments.

A.KH. and A.G. designed the model and the computational framework and analysed the data.

SS.H. wrote the manuscript with support from A.K. and A.KH.

All authors contributed to the interpretation of the results, discussed the results and contributed to the final manuscript.

All authors have read and approved the manuscript.

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Figures

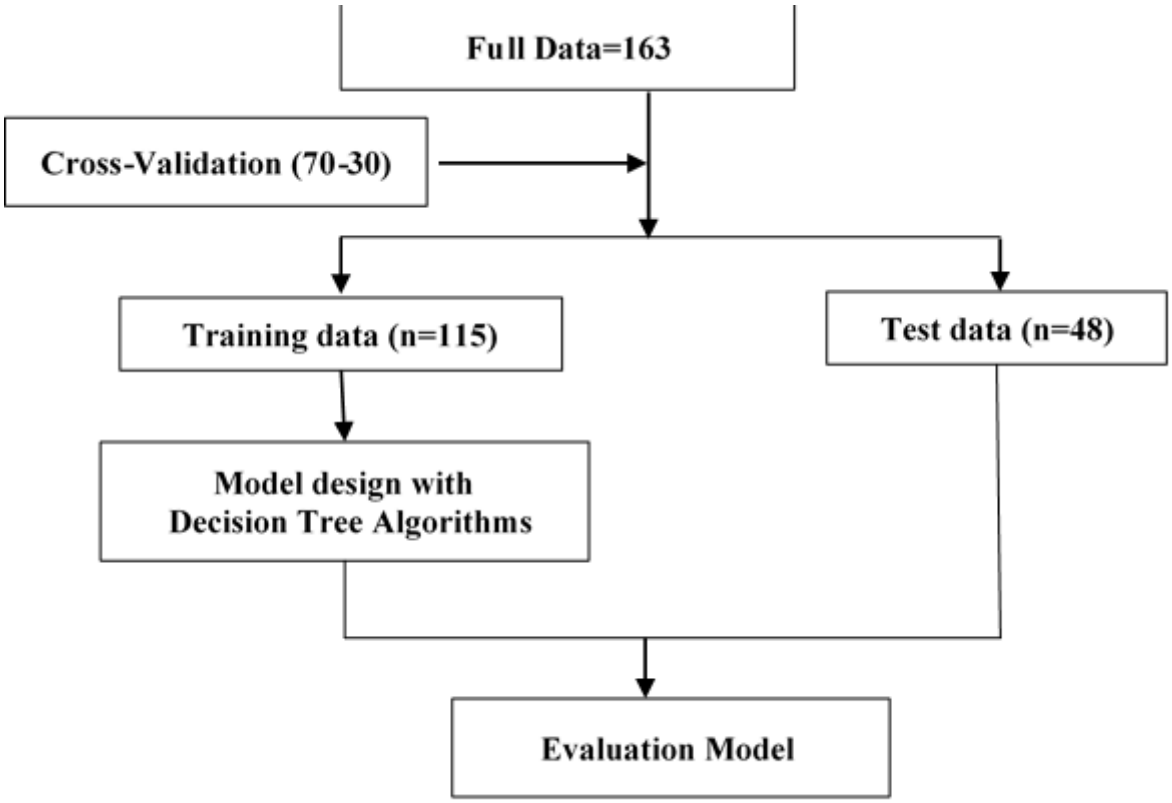

Figure 1

Structure of Implementation of Decision Tree Algorithm

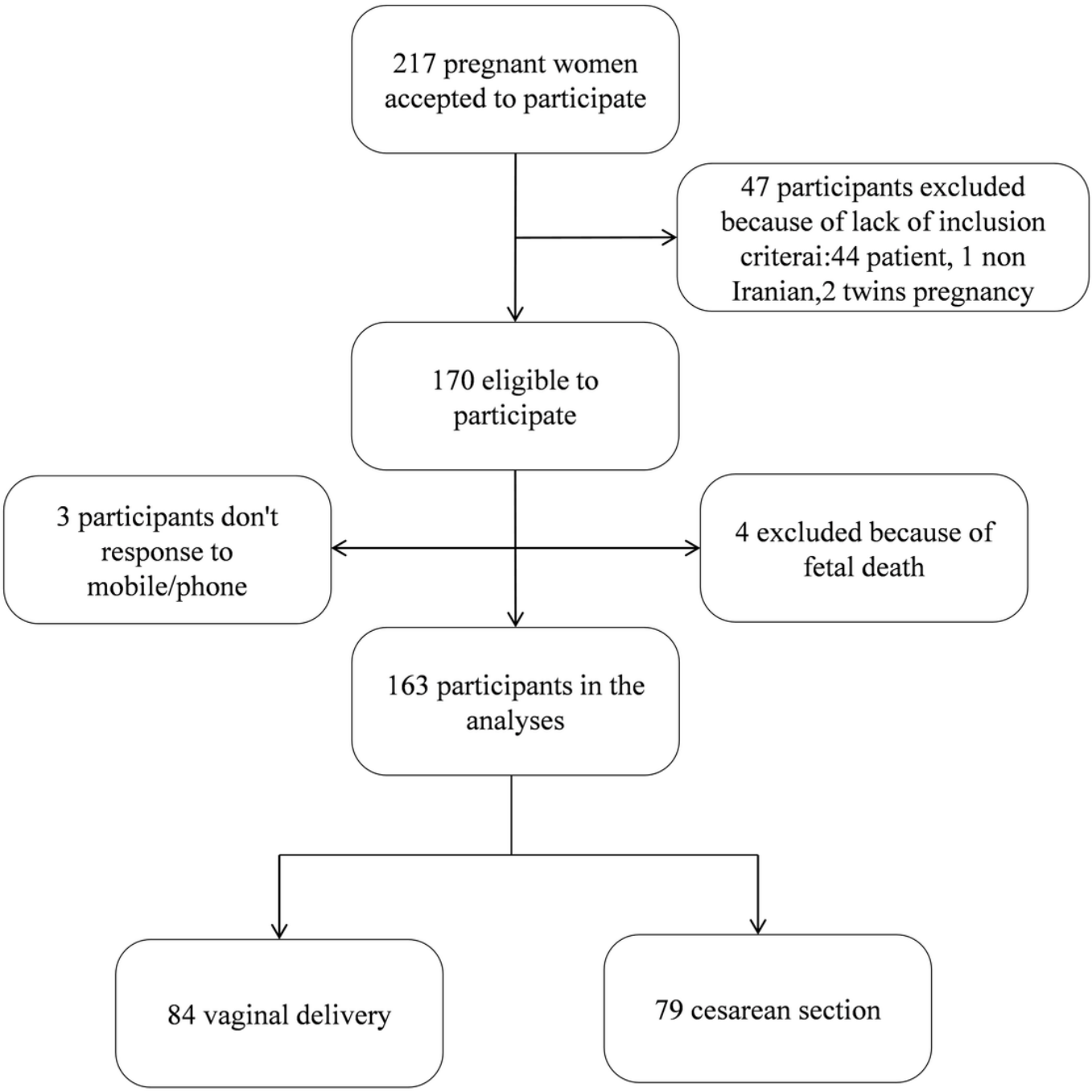

Figure 2

Flow chart illustrating the process of recruitment and follow-up of a pregnancy cohort.

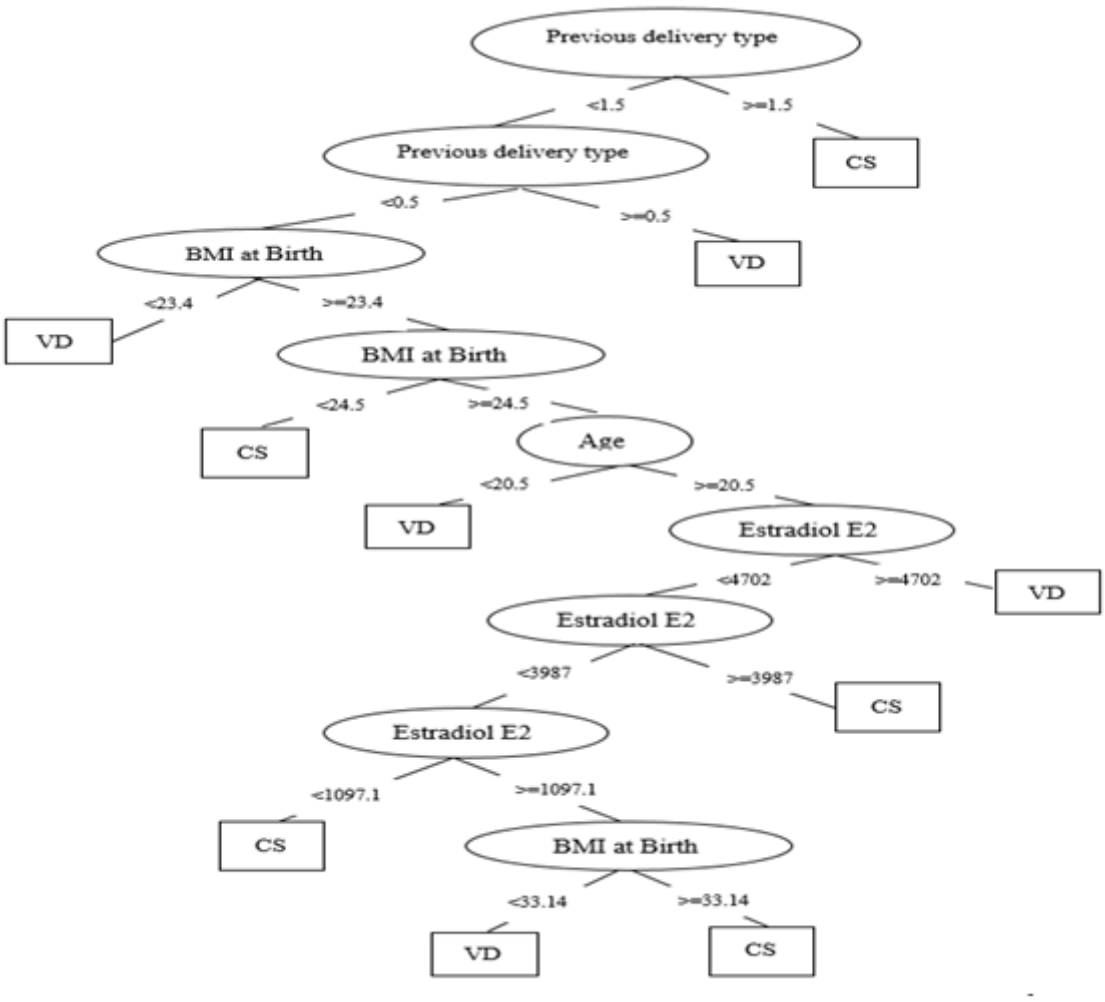

Figure 3

Proposed Tree Structure