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**RESEARCH** **Open Access**

# Prediction Model of Prolonged and Obstructed Labor in East Nusa Tenggara: A Multivariate Adaptive Regression Splines Analysis

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## Abstract

Prolonged and obstructed labor are the type of abnormal labor that may lead to maternal and fetal mortality. This study established the model for predicting prolonged and obstructed labor in East Nusa Tenggara. A health facilities-based case-control study was conducted in November 2017 among 570 women who gave birth at public health facilities in East Nusa Tenggara. Data were obtained by reviewing antenatal records, the mother's card, and partographs. In bivariate analysis, all variables with a p-value less than 0.25 determined by chi-square for categorical and independent t-test for numerical variables were included in multivariate analysis. Multivariate Adaptive Regression Splines (MARS) analysis was used to establish the final prediction model. The present study found that women <22, >26, and >34, with Hb levels of <12.5 gr%, and had nulliparity or multiparity (4 times) were reported as a higher risk of prolonged and obstructed labor. Meanwhile women with a fundal height of <34 cm, a height of >156 cm and >149 cm, a history of normal labor, presentation of the fetus behind the head, gestational weight gain of <12.3 kg, and pre-pregnancy BMI of <28.9 kg/m2 were identified as factors decreasing the risk of prolonged and obstructed labor. In conclusion, significant predictors of the outcome were maternal characteristics (age, parity, height, and history of labor method), maternal nutrition status (BMI pre-pregnancy, gestational weight gain, and hemoglobin levels), and fetal status (fundal height and fetal presentation).

**Keywords:** Prolonged Labor, Obstructed Labor, Prediction Model, MARS.

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## 1. INTRODUCTION

Prolonged and obstructed labor are part of the major causes of maternal mortality and morbidity, with almost 95% occurring in low and lower-middle-income countries (World Health Organization, 2020). Excessive duration of deliveries contributed 2.8% (95% CI: 1.4-5.5) to maternal deaths globally, with the highest average occurring in East Asia at 12.3% and 6.4% for Southeast Asia. (Say et al., 2014). In Indonesia, it accounts for 4.3 % of common complications during childbirth (Kementerian Kesehatan RI, 2018).

Prolonged and obstructed labor are common birth complications. Diagnosis of prolonged labor depends on careful monitoring of uterine contraction intensity, duration and frequency, cervical dilation, and descent of the fetus through the pelvis. A previous study defined prolonged labor as prolonging the duration of labor, typically in the first stage of labor (Nystedt & Hildingsson, 2014). It is an active labor that lasts for more than 12 hours. (World Health Organization, 2014). Meanwhile, obstructed labor (labor dystocia) is a failure to progress due to mechanical problems, such as a mismatch between fetal size, or more accurately, the size of the presenting part of the fetus, and the mother's pelvis, although some malpresentation, notably a brow presentation or a shoulder presentation (Ayenew, 2021).

Prolonged and obstructed labor impacts both the mother and the fetus. Women with long labors had an increased risk of a negative birth experience, which might lead to women avoiding childbearing or cesarean section (Walker et al., 2020; Zhu et al., 2019). *It also* increases disease incidence, such as the risk of postpartum hemorrhage, uterine rupture, maternal death to the mother, permanent brain damage, neonatal seizures, fetal hypoxia, and fetal death of the baby (Li et al., 2011).

Many *factors* can influence labor's progress. Common underlying causes include inefficient uterine contractions, abnormal fetal presentation or position, inadequate bony pelvis, or soft tissue abnormalities of the mother (World Health Organization, 2014). A similar previous study reported that parity, premature rupture of membranes, and fetal weight correlated with the incidence of prolonged labor (Sui et al., 2021). Being a referral from a lower health facility (AOR 6.80, 95% CI: 4.20–11.00) and prime parity (AOR 2.15, 95% CI: 1.26–3.66) also contribute to prolonged and obstructed labor (Musaba et al., 2020).

A few studies have identified factors associated with prolonged and obstructed labor, but these have only described limited risk factors and lacked information on the role of spontaneous vaginal deliveries in the studies (Ayenew, 2021; Musaba et al., 2020; Yeshitila et al., 2022). No study has documented the risk factors for prolonged and obstructed labor that represent the population of East Nusa Tenggara. In addition, the MARS approach in prediction study could capture the intrinsic complicated data mapping in high-dimensional data patterns. therefore, the present study could estimate the contributions of the input variables and established the predictors model for prolonged and obstructed labor using MARS analysis.

## 2. RESEARCH METHOD

This was a case-control study where the information was obtained by reviewing antenatal records, the mother's card, and partographs at all public health centers located in Kupang City, Kupang Regency, TTS, Rote-Ndao, and Sabu-Raijua on November 2017. The study population consisted of women who delivered at East Nusa Tenggara and registered in public health centers between 1 January – 31 December 2016. The Research Committee of the Faculty of Public Health, Airlangga University (No. 91-KEPK) reviewed and approved this research protocol.

Women eligible for the study were those women who had: (1) gestational age ≥ 38 weeks; (2) have a birth record, which consists of gestational age and delivery process, which is filled out on the partograph; (3) have a complete pregnancy record on the mother's card at every antenatal visit (1-1-2), which consists of age, parity, height, weight before pregnancy, weight in the 1st and 3rd trimesters, upper arm circumference, Hb levels in the 1st and 3rd trimesters, history of the maternal disease (allergic, chronic, infections or parasites), history of previous obstetric complications (abortion, premature rupture of membranes, stillbirth, prolonged labor), history of previous delivery methods (vacuum, forceps, section cesarean delivery), gestational age, number of fetuses, uterine fundal height, estimated fetal weight, fetal presentation, the position of the fetal head to pelvic inlet.

Prolonged or obstructed labor was defined as the progress of the labor, according to the partograph. If the opening of the cervix crosses the alert line, the woman who has long labor was recruited as the case (Dalal & Purandare, 2018). The controls were women who experienced normal birth patterns based on the notes on the partograph where the cervix did not cross the alert line, and both the mother and her baby were alive without complications and were declared healthy. The sample size was calculated to be 570 to obtain a power of 90% and a 5% significance level. The case and control groups were 285 women each.

The outcome of the study was the incidence of prolonged or obstructed labor. While the independent variables were: age during pregnancy, parity, BMI pre-pregnancy, gestational weight gain, upper arm circumference, Hb levels, history of the maternal disease (allergy, chronic, parasitic infections), maternal height, history of previous obstetric complications (abortion, premature rupture of membranes, stillbirth, prolonged labor), history of previous labor methods (normal, vacuum, forceps, cesarean section), gestational age, uterine fundal height, estimation of fetal weight, fetal presentation, the position of the fetal head to pelvic inlet.

The descriptive analysis uses frequency and percentage to describe categorical variables and the average value and standard deviation to describe numerical variables. Selecting research variables for multivariate analysis using the t-independent test for numerical variables and the Chi-Square test for categorical variables. Variables with p-value <0.25 will be included in the multivariate modeling. A predictive model for prolonged or obstructed labor is formed to analyze significant variables using the Multivariate Adaptive Regression Spline (MARS) Binary Logistics method. We determine the optimal model with the minimum GCV and MSE-test values and RMSE<1. The performance or the predictive ability of models of prolonged or obstructed labor events using the ROC Curve and the Hosmer and Lemeshow Test (Friedman, 1991).

## 3. RESULTS AND DISCUSSION

The descriptive characteristics of study participants are summarized in Table 1. A total of 570 women met the inclusion criteria; 285 experienced prolonged labor as the case group and 285 as the control group.

**Table 1.** Descriptive Characteristics of Study Participants

| **Characteristics** | **Prolonged Labor** | | **Total (N= 570)** | **p-value** |
|---|---|---|---|---|
| | **Cases (n= 285)** | **Control (n= 285)** | | |
| Age (Mean ± SD) | 32.1 ± 5.8 | 26.7 ± 5.0 | 29.4 ± 6.1 | |
| < 20 | 22 (7,7%) | 15 (5,3%) | 37 (6,5%) | <0.001*) |
| 20 – 35 | 185 (64,9%) | 255 (89,4%) | 440 (77,2%) | |
| > 35 | 78 (27,4%) | 15 (5,3%) | 93 (16,3%) | |
| **Parity** | | | | |
| Nulliparity (0) | 108 (37,9%) | 72 (25,3%) | 180 (31,6%) | 0.005**) |
| Primiparity (1) | 73 (25,6%) | 81 (28,4%%) | 154 (27,0%) | |

| | | | | |
|---|---|---|---|---|
| Multiparity (2) | 30 (10,5%) | 61 (21,4%) | 91 (16,0%) | |
| Multiparity (3) | 33 (11,6%) | 51 (17,9%) | 84 (14,7%) | |
| Multiparity (≥ 4) | 41 (14,4%) | 20 (7,0%) | 61 (10,7%) | |
| Height (Mean ± SD) | 149.9 ± 3.5 | 154.1 ± 5.0 | 152.0 ± 4.8 | |
| < 145 cm | 15 (5,3%) | 6 (2,1%) | 21 (3,7%) | <0.001*) |
| 145 – 149 cm | 111 (38,9%) | 46 (16,1%) | 157 (27,5%) | |
| 150 – 154 cm | 138 (48,4%) | 92 (32,3%) | 230 (40,4%) | |
| 155 – 159 cm | 16 (5,6%) | 99 (34,7%) | 115 (20,2%) | |
| ≥ 160 | 5 (1,8%) | 42 (14,8%) | 47 (8,2%) | |
| **Childbirth Complications** | | | | |
| No | 230 (80,7%) | 251 (88,1%) | 481 (84,4%) | 0.021**) |
| Premature rupture of membranes | 13 (4,6%) | 6 (2,1%) | 19 (3,3%) | |
| Prolonged labor | 9 (3,1%) | 6 (2,1%) | 15 (2,6%) | |
| Stillbirth | 12 (4,2%) | 5 (1,7%) | 17 (3,0%) | |
| Abortion | 21 (7,4%) | 17 (6,0%) | 38 (6,7%) | |
| **Labor method** | | | | |
| Never | 108 (37,9%) | 72 (25,3%) | 180 (31,6%) | 0.001**) |
| Vaginal spontaneous | 163 (57,2%) | 213 (74,7%) | 376 (65,9%) | |
| Vacuum assist/ Forcep | 14 (4,9%) | 0 (0,0%) | 14 (2,5%) | |
| Cesarean Section | 0 (0,0%) | 0 (0,0%) | 0 (0,0%) | |
| **Disease history** | | | | |
| No | 280 (98,2%) | 283 (99,3%) | 563 (98,8%) | 0.246**) |
| Yes (Malaria) | 5 (1,8%) | 2 (0,7%) | 7 (1,2%) | |
| Pre-pregnancy BMI (kg/ $m^2$) (Mean ± SD) | 23.2 ± 2.8 | 21.6 ± 2.9 | 22.4 ± 2.8 | |
| < 18,5 | 49 (17,2%) | 53 (18,6%) | 102 (17,9%) | <0.001*) |
| 18,5 – 24,9 | 174 (61,1%) | 204 (71,6%) | 378 (66,3%) | |
| 25 – 29,9 | 58 (20,3%) | 26 (9,1%) | 84 (14,7%) | |
| ≥ 30 | 4 (1,4%) | 2 (0,7%) | 6 (1,1%) | |
| Upper arm circumference (cm) (Mean ± SD) | 24.9 ± 2.6 | 24.4 ± 2.4 | 24.6 ± 2.5 | |
| < 23,5 | 64 (22,5%) | 58 (20,4%) | 122 (21,4%) | 0.001*) |
| ≥ 23,5 | 221 (77,5%) | 227 (79,6%) | 448 (78,6%) | |
| Hemoglobin Levels in the Third Trimester (gr%) (Mean ± SD) | 10.4 ± 1.05 | 11.1 ± 1.06 | 10.7 ± 1.03 | |
| < 8,0 | 3 (1,0%) | 1 (0,4%) | 4 (0,7%) | <0.001*) |
| 8,0 – < 11,0 | 174 (61,1%) | 130 (45,6%) | 304 (53,3%) | |
| ≥ 11,0 | 108 (37,9%) | 154 (54,0%) | 262 (46,0%) | |
| Weight gain during pregnancy (kg) (Mean ± SD) | 12.2 ± 1.91 | 11.7 ± 1.98 | 12.0 ± 1.96 | |
| < 9,0 | 7 (2,4%) | 25 (8,8%) | 32 (5,6%) | 0.001*) |
| 9,0 – 16,0 | 267 (93,7%) | 257 (90,2%) | 524 (91,9%) | |
| > 16,0 | 11 (3,9%) | 3 (1,0%) | 14 (2,5%) | |

| | | | | |
|---|---|---|---|---|
| Gestational age (week) (Mean ± SD) | 40.0 ± 0.95 | 39.5 ± 0.98 | 39.8 ± 0.99 | |
| 38 – 41 | 283 (99,3%) | 284 (99,6%) | 567 (99,5%) | <0.001*) |
| > 41 | 2 (0,7%) | 1 (0,4%) | 3 (0,5%) | |
| Fundal height (cm) (Mean ± SD) | 33.2 ± 1.1 | 31.8 ± 0.8 | 32.5 ± 1.17 | |
| < 31 | 0 (0,0%) | 6 (2,1%) | 6 (1,1%) | <0.001*) |
| 31 – 35 | 273 (95,8%) | 279 (97,9%) | 552 (96,8%) | |
| > 35 | 12 (4,2%) | 0 (0,0%) | 12 (2,1%) | |
| Estimation of fetal weight (gram) (Mean ± SD) | 3360.5 ± 174.98 | 3147.1 ± 146.10 | 3258.8 ± 190.52 | |
| 2500 – 2999 | 0 (0,0%) | 47 (16,5%) | 47 (8,3%) | <0.001*) |
| 3000 – 3500 | 231 (81,1%) | 236 (82,8%) | 467 (81,9%) | |
| > 3500 | 54 (18,9%) | 2 (0,7%) | 56 (9,8%) | |
| **Position of the fetal head to the pelvic inlet** | | | | |
| In | 150 (52,6%) | 165 (57,9%) | 315 (55,3%) | 0.238**) |
| Not in yet | 135 (47,4%) | 120 (42,1%) | 255 (44,7%) | |
| Fetal presentation | | | | |
| Top of head | 20 (7,0%) | 2 (0,7%) | 22 (3,9%) | <0.001**) |
| Back of head | 265 (93,0%) | 283 (99,3%) | 548 (96,1%) | |

**t-independent test; **Chi-square test; ) statistically significant*

The results showed that most subjects who experienced prolonged labor were older (average aged 32.1), in parity of first children (37.9%), and had lower average height (149.9 cm). Of the 570 study subjects, it was found that most of the mothers (84.4%) had never experienced a history of complications in previous labors, and the remaining 15.6% had experienced a history of complications of childbirth such as abortion, premature rupture of membranes, prolonged labor, or stillbirth. Most subjects in both groups delivered spontaneously vaginally, and only 1.2% had a history of illness (malaria). Those who experience prolonged labor have an average pre-pregnancy BMI higher (23.2 $kg/m^2$) than women with normal delivery (21.6 $kg/m^2$).

The average size of the upper arm circumference in the first trimester of women with prolonged labor was slightly larger (24.9 cm) than that of women with normal delivery (24.4 cm). Meanwhile, women who experienced prolonged labor had lower hemoglobin levels in the third trimester (10.4 gr%), a more significant weight gain during pregnancy (12.2 kg), a slightly longer gestational age at delivery (40 weeks), and had a higher fundal height (33.2 cm) than in control. The estimated fetal weight calculated at gestational age ≥ 38 weeks is heavier (3360.5 grams) in women who experience prolonged labor than in women with normal delivery. It can be seen that almost the same percentage of mothers with the position of the fetal head enter the pelvic inlet during labor between cases and controls. Most subjects with back-of-the-head presentations experienced long labor progress and normal labor progress. Multivariate analysis should include all the independent variables (p-value <0.25).

**Table 2.** Results of Optimal Model Selection with the MARS Method for Predicting Prolonged and Obstructed Labor.

| MARS[1] Model | GCV[2] | MSE-test[3] | RMSE[4] |
|---|---|---|---|
| Model without interaction | 0.0804 | 0.0816 | 0.2691 |
| A model with the interaction of two variables | 0.0863 | 0.0863 | 0.2817 |
| Maximum interaction of all variables | 0.0925 | 0.0876 | 0.2915 |

[1]*Multivariate Adaptive Regression Splines;* [2]*Generalized cross-validation;* [3]Mean Square Error*;* [4]*Root Mean Square Error*

Table 2 shows the results of the optimal model selection between three models with 30 basis functions and validated with 10-fold cross-validation. The best prediction model was the MARS model without interaction with the lowest GCV (0.0804), the lowest MSE-test (0.0816), and RMSE <1 (0.2691).

**Table 3.** Results of Selection of Predictor Variables Included in the MARS Model

| Predictor | Importance Scale | GCV |
|---|---|---|
| Age | 100.00* | 0.1294 |
| Fundal height | 72.51* | 0.1062 |
| Maternal height | 47.37* | 0.0914 |
| Hemoglobin levels | 29.63* | 0.0848 |
| Parity | 25.52* | 0.0837 |
| Delivery method | 16.66* | 0.0818 |
| Fetal presentation | 13.97* | 0.0814 |
| Gestational weight gain | 8.08* | 0.0808 |
| BMI | 5.46* | 0.0806 |
| Obstetric Complications History | 0.0 | 0.0805 |
| History of illness | 0.0 | 0.0805 |
| Estimation of fetal weight | 0.0 | 0.0805 |
| Upper arms circumference | 0.0 | 0.0805 |
| Gestational age | 0.0 | 0.0805 |
| Position of the fetal head to the pelvic inlet | 0.0 | 0.0805 |

**Important contribution variables*

From the selected MARS model, the contribution of the predictor variable was identified based on the predictor variable that minimized the GCV value with a rating scale of 0–100. Variables considered essential in the predictive model of prolonged or obstructed labor were age, uterine fundal height, body height, hemoglobin level, parity, history of delivery, fetal presentation, gestational weight gain, and prepregnancy BMI.

**Table 4.** Final MARS Model for Predicting Prolonged and Obstructed Labor.

| Predictors | Regression Equation | Coefficient | Std. Error | t | p-value |
|---|---|---|---|---|---|
| Intercept | | 0.6419 | 0.0829 | 7.7367 | <0.001 |
| Age | | | | | |
| BF 4 | Max (0. 22 – age) | 0.0850 | 0.0113 | 7.5234 | <0.001 |
| BF 17 | Max (0. age – 26) | 0.0705 | 0.0148 | 4.7499 | <0.001 |
| BF 13 | Max (0. age – 34) | 0.0869 | 0.0051 | 16.8856 | <0.001 |
| Fundal height | | | | | |
| BF 2 | Max (0. 34 – fundal height) | -0.1723 | 0.0127 | -13.5814 | <0.001 |

| | | | | | |
|---|---|---|---|---|---|
| Height | | | | | |
| BF 5 | Max (0. height – 149) | -0.0300 | 0.0051 | -5.8824 | <0.001 |
| BF 19 | Max (0. height – 156) | -0.0165 | 0.0116 | -1.4217 | 0.0018 |
| Hemoglobin levels | | | | | |
| BF 10 | Max (0. 12.5 – Hemoglobin) | 0.0679 | 0.0115 | 5.9043 | <0.001 |
| Parity 0 or 4 | | | | | |
| BF 11 | (Parity in (0. 4)) | 0.1603 | 0.0308 | 5.2079 | <0.001 |
| History of labor method | | | | | |
| BF 7 | (Labor method (spontan)) | -0.1237 | 0.0326 | -3.7894 | 0.0002 |
| Fetal presentation | | | | | |
| BF 15 | (Fetal presentation (back of the head)) | -0.2058 | 0.0606 | -3.3985 | 0.0007 |
| Gestational weight gain | | | | | |
| BF 22 | Max (0. 12.3 – Gestational weight gain) | -0.0150 | 0.0094 | -1.6019 | 0.0079 |
| Pre-pregnancy BMI | | | | | |
| BF 24 | Max (0. 28.9 – BMI) | -0.0146 | 0.0060 | -2.4286 | 0.0155 |
| $R^2$ = 0.7104. $(R – 0)^2$ = 0.8552 | | | | | F = 113.8859 |
| $R^2$ Adj = 0.7042 | | | | | p = <0.001 |

Regression Equation:

Y = 0.6419 + 0.0850 max (0. 22 – age) + 0.0705 max (0. age – 26) + 0.0869 max (0. age – 34) - 0.1723 max (0. 34 – fundal height) - 0.0300 max (0. height – 149) - 0.0165 max (0. height – 156) + 0.0679 max (0. 12.5 – Hemoglobin) + 0.1603 (Parity 0 or 4) - 0.1237 (Spontan delivery method) - 0.2058 (Fetal presentation back of the head) - 0.0150 max (0. 12.3 – Pregnant weight gain) - 0.0146 max (0. 28.9 – Pre-pregnancy BMI);

Probability (Y = 1) = π(x) as mothers with prolonged or obstructed labor

Probability (Y = 0) = 1 – π(x) as mothers with normal labor

**BF: Basis Functions*

Table 4 describes the final MARS model without interaction for predicting the incidence of prolonged or obstructed labor under empirical data. Overall, a p-value <0.001 was obtained and could explain 70.42% of the variation in the probability of prolonged or obstructed labor ($R^2$Adj = 0.7042), so it can be concluded that the model can be accepted as a regression equation to predict the probability of prolonged or obstructed labor on subjects with specific characteristics. Risk indicators that can increase the occurrence of prolonged and obstructed labor, in order of highest risk level were fetal presentation, uterine fundal height, parity, history of labor method, age, hemoglobin levels, maternal height, gestational weight gain, and BMI pre-pregnancy.

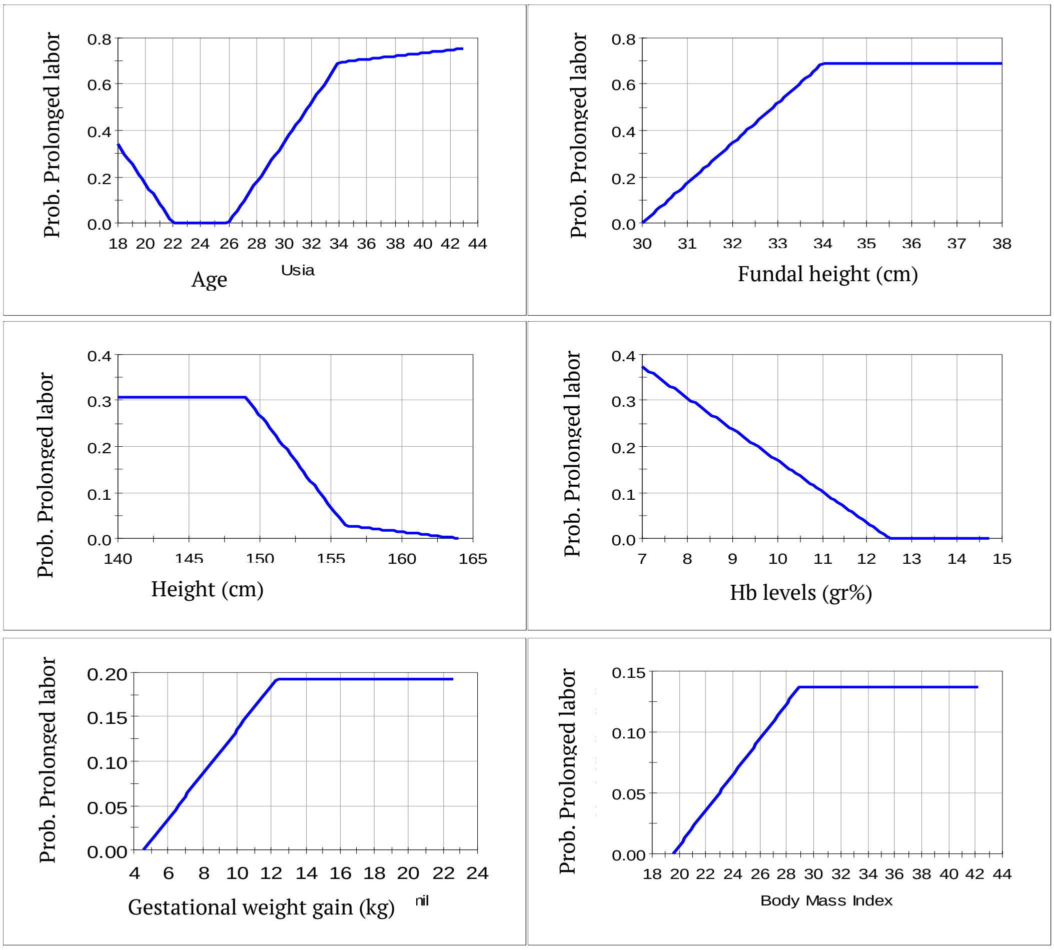


**Figure 1.** Curve Relationship of Probability of Prolonged and Obstructed Labor for Numerical Variables in the MARS Model without Interaction.

The relationship pattern of prolonged or obstructed labor events with continuous predictor variables included in the model is shown in Figure 1. The risk of prolonged or obstructed labor will increase in women under 22 years old, more than 26 years old, and more than 34 years old, with Hb levels of less than 12.5 gr%, and mothers with nulliparity or multiparity (4 times). In contrast, the risk of prolonged or obstructed labor will decrease in women with a fundal height of less than 34 cm, a height of more than 156 cm and more than 149 cm, a history of spontaneous delivery, presentation of the fetus behind the head, gestational weight gain of less than 12.3 kg, or a pre-pregnancy BMI of less than 28.9 kg/m$^2$.

Age was found to be significantly associated with the incidence of prolonged and obstructed labor. The present findings are consistent with previous literature that women aged less than 20 years old and advanced maternal age (≥35 years old) had significant odds for various maternal complications, such as severe preeclampsia, eclampsia, postpartum hemorrhage, fetal distress, and poor fetal growth (Cavazos-Rehg et al., 2015; Lundborg et al., 2021). Those at risk of age for pregnancy experiencing prolonged labor are 25.9% (Wulansari et al., 2022). However, a slightly different result was found in this study that women aged more than 26 years old also increasingly developed prolonged labor.

Severe anemia or lower hemoglobin levels is also crucial for pregnant women. It antedates pregnancy is aggravated by increasing requirements during pregnancy, blood loss at delivery, and infections in the antenatal and postnatal periods. Severe anemia was proven to be associated with increased operative deliveries and prolonged labor (Malhotra et al., 2002).

Higher blood loss may be attributed to impaired uterine muscle strength for labor, affecting labor duration (Kumari et al., 2019).

Around 37.9% of cases in the current study were those with nulliparity. This is slightly different from a previous result that only primiparity (AOR = 7.74: 95%CI = 2.13, 18.2) caused higher odds of longer duration of labor (Musaba et al., 2020). However, the MARS model found different results that mothers with nulliparity or multiparity (4 times) increase the risk of developing prolonged or obstructed labor. This may be caused by other dominant studied factors.

Although this study has statistically proven fundal height can predict prolonged and obstructed labor, little literature has been published. It has been found in Thailand that the cut point for uterine fundus height predicts an increased risk of cesarean section delivery due to cephalopelvic disproportion at a size of more than 35 cm (Khunpradit et al., 2007). A similar finding of the present research is that the risk of prolonged or obstructed labor will decrease in women with a fundal height of less than 34 cm.

The results showed that a history of normal delivery methods was a predictor of a decrease in the incidence of prolonged labor. Table 1 presents 36.9% of all studied subjects had normal labor, meaning that they were exposed to oxytocin augmentation. Women with augmentation of labor decreased risk of emergency cesarean section (aRR 0.62, 95% CI 0.59-0.66) (Litorp et al., 2021).

It is also well-established that physical factors such as maternal height affect labor. The present result shows that the risk of prolonged and obstructed labor decrease gradually at a height of more than 156 cm and more than 149 cm. Existing studies have supported that shorter maternal height was associated with a higher frequency of caesarian section, low birth weight newborns, stillbirths, and prolonged obstructed labor (Myklestad et al., 2013; Stulp et al., 2011; Wu et al., 2021). This is because short-statured women tend to have *narrow pelvic areas which* are related to prolonged obstructed labor (Marbaniang et al., 2022).

A study in Mojo Town, Central Ethiopia has shown 16% of women experience obstructed labor and 66% are caused by cephalo-pelvic disproportion, and 22% account for malpresentation (Girma et al., 2022). Fetal malpresentation and malposition were identified as other causes of prolonged and obstructed labor (Ayenew, 2021) leading *to a greater risk of cesarean delivery* (Senécal et al., 2005). Therefore, longer durations may be appropriate to reassure maternal and fetal status and continued descent of the fetal presenting part (Gill et al., 2023).

In this study, gestational weight gain of less than 12.3 kg and a pre-pregnancy BMI of less than 28.9 kg/m$^2$ statistically proved to be associated with declining the risk of prolonged labor. Previous studies suggested that compared to normal-weight women, overweight and obese women have a prolonged duration of labor (Ellekjaer et al., 2017; Schuster et al., 2016; Zhou et al., 2019). Obese women were more likely to have a prolonged second stage (Frolova et al., 2021). Obesity during pregnancy may decline the contractility of abdominal muscles, resulting in suboptimal use of abdominal pressure during labor and lack of productive force, leading to prolonged labor (Zhou et al., 2019). This also resulted in a higher risk of cesarean delivery for overweight and obese compared to normal-weight women (Ellekjaer et al., 2017). Maternal obesity risks the newborn's life by increasing the risk for macrosomia, fetal distress and low Apgar score, hypoglycemia, and meconium aspiration (Schuster et al., 2016). More weight gain than recommended for maternal obesity and pregnancy leads to less breastfeeding (Marchi et al., 2015). Another finding reported that an effect modification between BMI and maternal age contributes to the longer duration of labor.

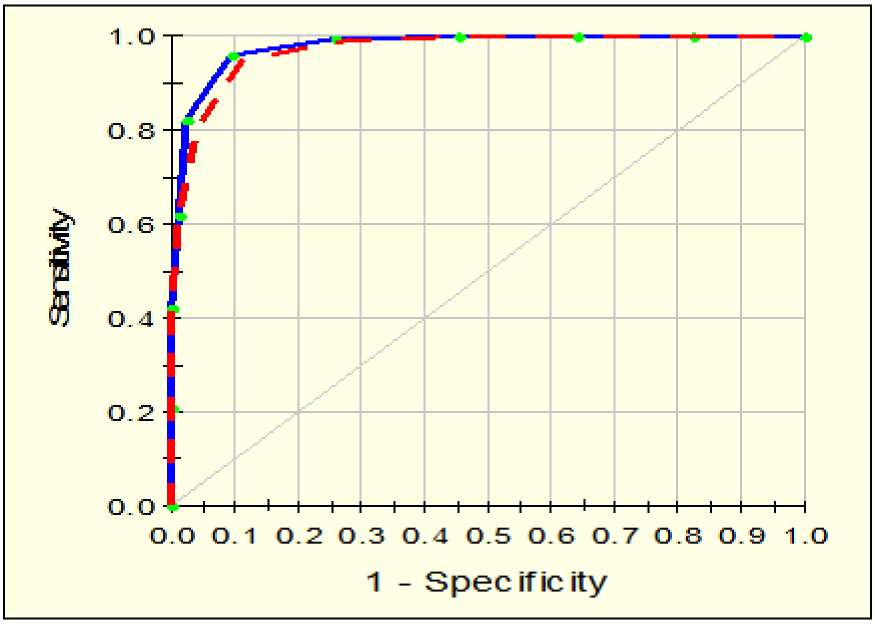


**Figure 2.** MARS Model ROC Curve for Predicting Prolonged and Obstructed Labor.

The performance of the MARS model prediction of prolonged and obstructed labor has been statistically measured from the results of the above ROC curve test. The results of the test-sample ROC curve showed a value of 0.974 (95% CI: 0.963-0.984). A slight decrease in the AUC value of only 0.01 after the model was validated. The learn-sample ROC curve and the test-sample ROC curve nearly coincide; this shows that the difference in AUC values can be neglected. The Hosmer-Lemeshow test sample yields a p-value of 0.348 (> 0.05); thus, the selected MARS model had good statistical quality and properly can be used to compile a risk index for preventing prolonged or obstructed labor.

This study benefited from its case-control design, accuracy in determining case subjects, and involving all registered pregnant women in primary health facilities in East Nusa Tenggara province; thus, the study represents the source population. However, we also acknowledge that the use of secondary data from partograph records and mother's cards is a limitation in this study. The subjectivity of data collection may be biased toward the results that we are unable to control.

## 4. CONCLUSION

Prolonged and obstructed labor is a complicated condition that may cause maternal death. Significant risk factors used to predict the likelihood of prolonged and obstructed labor are maternal characteristics (age, parity, height, and history of labor method), maternal nutrition status (BMI pre-pregnancy, gestational weight gain, and hemoglobin levels), and status of the fetus that is determined by the fundal height and fetal presentation. Future studies need to use a cohort study design by including the variable of the feet length and an etiological conceptual framework to determine the relationship between age in the normal reproductive period (20-35 years) and its confounding factors for dystocia.

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