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Results of fetal health assessment tests in pregnancies with borderline and normal amniotic fluid index: A case-control study

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ABSTRACT

Background: There is currently insufficient evidence to support routine fetal surveillance or early delivery decisions in cases of borderline Amniotic Fluid Index (AFI).
Objective: This study aimed to compare the results of fetal health assessment tests in pregnancies with borderline and normal AFI.
Methods: This case-control study was conducted on 300 pregnant women (150 with normal AFI and 150 with borderline AFI) at the 29 Bahman Hospital in Tabriz-Iran. Due to the small number of mothers with borderline AFI, all pregnant mothers with borderline AFI were recruited (census sampling). For the control group, mothers with normal AFI were selected using matched sampling based on age, parity, and gestational age to correspond to the borderline group. The data were collected using a four-part researcher-made questionnaire.
Results: A significant difference was observed in the reduction of maternal perception of fetal movements between the two groups ($p = 0.0001$), with 35 (23.3 %) women in the normal AFI group and 46 (30.7 %) women in the borderline AFI group reporting reduced movements. The groups had no significant differences regarding Non-Stress Test (NST) ($p = 0.324$) and Biophysical Profile (BPP) ($p = 0.442$) results. In women with borderline AFI, maternal perception of decreased fetal movement was 7 times more likely than in women with a normal AFI (OR = 7.43; 95 %CI: 4.4 to 12.4; $p = 0.0001$).
Conclusion: The results of fetal health assessment tests in women with borderline AFI were similar to those with normal AFI. Therefore, clinical management of borderline AFI cases may be approached similarly to those with normal AFI.

1. Background

Amniotic fluid is a clear liquid that surrounds the fetus during pregnancy, providing a supportive environment for the normal growth and development of the fetus throughout gestation. Amniotic fluid allows the fetus to grow in a sterile environment with appropriate temperature regulation. Additionally, the fluid protects the fetus from trauma and infection due to its moisturizing and bacteriostatic properties and helps prevent the compression of the umbilical cord and placenta (Rathod and Samal, 2017).

A normal level of AFI indicates proper functioning of the developing fetus, while a low amount can be associated with incomplete lung development and poor fetal growth (Kehl et al., 2016, Cunningham FG, 2020). The quantity of amniotic fluid is semi-quantitatively assessed using ultrasound through the Amniotic Fluid Index, which is calculated by adding the depth in centimeters of the maximum vertical pocket (MVP) in each of the four equal quadrants of the uterus. An AFI between 8.1 and 24 cm is considered normal (Cunningham, 2020). Oligohydramnios reduces amniotic fluid volume relative to gestational age, with an AFI of 5 cm or less (Kehl et al., 2016, Cunningham, 2020, Choi, 2016).

Borderline AFI is diagnosed when AFI is between 5.1 and 8 cm (Cunningham, 2020). Compared to a normal AFI, the occurrence of an

Abbreviations: NST, Nonstress test; BPP, Biophysical profile; AFI, Amniotic Fluid Index; FHR, Fetal Heart Rate; LMP, Last Menstrual Period.

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AFI between 5.1 and 8 cm varies across studies from 6 % to 44 %, with an overall prevalence of 12 % reported (Rathod and Samal, 2017). Huntly et al. found that approximately 73 % of pregnancies with borderline AFI will have normal AFI values in subsequent ultrasound examinations. However, in 27 % of cases, the borderline AFI persists or progressively declines, leading to clear oligohydramnios (Huntley et al., 2022).

Given the importance of delivering healthy babies, there is significant interest in assessing fetal health (Cunningham, 2020, Joshi and Dangal, 2022). Maternity care providers initiate various prenatal monitoring methods to ensure timely, reliable, and appropriate delivery. Current methods for predicting fetal health focus on physical activities such as Fetal Heart Rate)FHR(, movement, breathing, and amniotic fluid (Cunningham, 2020, Choudhary et al., 2020).

Fetal movement counting by the mother is one of the oldest and simplest methods for assessing fetal health in the late second and third trimesters (Mangesi et al., 2015) and can be easily performed by all pregnant women (Ricci, 2017). The effectiveness of fetal movement counting is supported by the mother perceiving at least 87 % of all fetal movements (AlAmri and Smith, 2021, Turner et al., 2021). Mother's assessment of fetal movement in pregnancies with no complications can be a good predictor of fetal status, as women without pre-pregnancy or pregnancy-related health issues tend to report healthy fetal movements (Khalid and Khalid, 2023, Sheikh et al., 2014).

Reduced fetal movement is associated with decreased amniotic fluid levels (Komariah and Wahyuni, 2023). Einspieler et al. (2021) demonstrated that 64 % of pregnancies with reduced amniotic fluid also exhibited decreased fetal movement (Einspieler et al., 2021). Adverse perinatal outcomes are more frequently observed in cases of reduced fetal movement among patients with oligohydramnios compared to those with borderline AFI (El-sayed et al., 2023b). Fetal movement counting by the mother may enable timely interventions by healthcare providers to improve outcomes. However, it may also lead to unnecessary anxiety in pregnant women or result in unnecessary interventions (Hantoushzadeh et al., 2024).

Another method for assessing fetal health is the NST, introduced by Sadowski in 1973. Subsequent studies have validated its effectiveness as a screening tool for identifying at-risk fetuses (Jain and Acharya, 2022). Lee and Freeman described the NST as a test that measures "acceleration in FHR in response to fetal movement" as an indicator of fetal well-being. This test uses Doppler technology and is currently the most commonly used method for evaluating fetal health (Cunningham, 2020). Such monitoring can be conducted in a structured outpatient setting with trained personnel who thoroughly understand FHR monitoring technology (Nageotte, 2024).

The Biophysical Profile (BPP) test is commonly used to assess fetal health and diagnose the presence of hypoxia and acidosis in the fetus. However, in 27 % of cases, the borderline AFI persists or continuously decline (Gomez et al., 2024). Interventions based on abnormal BPP results have been shown to reduce perinatal mortality and decrease the incidence of cerebral palsy (Berghella, 2012). Krishna et al. (2023) conducted a study comparing the use of NST and BPP for assessing fetal health before birth. They found that both criteria are highly suitable for predicting adverse outcomes in mothers. However, they noted that access to NST is significantly easier (Das and Saha, 2023).

The study by revealed a statistically significant difference between the rates of fetal distress, meconium-stained amniotic fluid, abnormal FHR, and low Apgar scores in fetuses with borderline amniotic fluid levels compared to those with normal amniotic fluid levels (El-sayed et al., 2023a). Similarly, Tithy et al. (2022) found that adverse outcomes, including abnormal FHR, fetal growth restriction, low birth weight, and low Apgar scores, were more frequent in oligohydramnios than borderline AFI (Tithy, 2022). In the study by Asgharian et al. (2013), it was shown that low birth weight, neonatal intensive care unit (NICU) admissions, low Apgar scores at 5 min, delayed growth, fetal distress, and preterm labor were more common among infants born to mothers with borderline AFI compared to those with normal index (Asgharnia et al., 2013). Additionally, Sadia et al. (2022) reported an increase in adverse pregnancy outcomes, including Apgar scores below 7, fetal distress, and meconium-stained amniotic fluid among mothers with borderline AFI (Sadia et al., 2022).

Amniotic fluid index (AFI) in term pregnancies remains a subject of ongoing debate. While several studies have associated borderline AFI with increased risks of adverse perinatal outcomes, such as low birth weight, higher rates of cesarean delivery, and non-reassuring fetal status (El-Sayed et al., 2023a; Jamal et al., 2016; Yadav et al., 2021), other investigations have failed to establish a definitive correlation, particularly in the absence of concomitant high-risk conditions (Choi, 2016; Kehl et al., 2016; Sekhon et al., 2021). This discrepancy underscores the need for further high-quality evidence to elucidate the potential implications of borderline AFI on maternal and neonatal outcomes. Therefore, the present study seeks to systematically evaluate and compare perinatal outcomes in term pregnancies with borderline versus normal AFI. The findings aim to inform clinical decision-making and improve obstetric care.

2. Research hypotheses

The results of fetal health assessment tests are different in pregnancies with normal and borderline AFI.

1- The results of maternal fetal movement perception are different in pregnancies with normal and borderline AFI.

2- The results of non-stress testing are different in pregnancies with normal and borderline AFI.

3- The results of biophysical profile testing are different in pregnancies with normal and borderline AFI.

3. Methods and materials

3.1. Study Design, area and period

This case-control study was conducted on pregnant women with normal AFI (control group) and borderline AFI (case group) at 29 Bahman Hospital, Tabriz, Iran, from 2022 to 2023. 29 Bahman Hospital is a specialized facility affiliated with the Social Security Organization, providing comprehensive free healthcare services to insured patients. The hospital is equipped with active labor wards, a NICU, and advanced radiology departments, ensuring high-quality maternal and fetal care.

3.2. Study and source population

All eligible pregnant women with gestational age $\geq$ 34 weeks were included. Inclusion criteria for the study were as follows: willingness to participate, singleton pregnancy, gestational age of 34 weeks or more based on the last menstrual period (LMP) or first-trimester ultrasound, absence of fetal abnormalities, no diagnosed maternal medical conditions or risk factors (such as pregnancy-induced hypertension, pre-existing hypertension, preeclampsia, overt diabetes, gestational diabetes, etc.), intact fetal membranes at admission, and completion of AFI ultrasound at the radiology department of 29 Bahman Hospital. Exclusion criteria included fetal death, significant fetal anomalies, excessive bleeding at admission, contraindications for vaginal delivery (such as non-cephalic presentation, macrosomia, placenta previa, etc.), and a history of cesarean section.

3.3. Sample size, technique and procedures

The sample size for this study was estimated using the following formula:

$$n = \frac{\left(Z_{1-\alpha 12} + Z_{1-\beta}\right)\left[P_1(1-P_1) + P_2(1-P_2)\right]}{\left(P_1 - P_2\right)^2}$$

In the present study, considering an acceptable error of 0.05, a confidence level of 95 %, and a power of 80 %, and based on the survey by Jamal et al. (Jamal et al., 2016), which reported a cesarean section rate of 43 % in the borderline AFI group and 28 % in the normal AFI group, the required sample size for each group was calculated to be at least 150 participants.

Sampling was conducted after obtaining ethical approval from the Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1400.003) and receiving an introductory letter to 29 Bahman Hospital. Prior to data collection, all eligible pregnant women were provided with comprehensive information about the study objectives, voluntary participation, their right to withdraw at any time without any consequences, and the confidentiality of their data. Written informed consent was obtained from each participant. The researcher's presence in the labor room was permitted only after obtaining explicit written and verbal permission from each participant, ensuring respect for their autonomy and comfort. Additionally, all collected data were recorded anonymously to maintain the participants' privacy and confidentiality. The researcher then visited the delivery room at 29 Bahman Hospital and reviewed the records of pregnant women admitted. Based on the AFI reported in the ultrasound, participants were divided into two groups: normal AFI (8.1 to 24 cm) and borderline AFI (5 to 8 cm). It is important to note that the most recent ultrasound, conducted at the radiology center of 29 Bahman Hospital and reporting the AFI, was considered valid for this study. Due to the small number of mothers with borderline AFI, all pregnant mothers with borderline amniotic fluid index (AFI) admitted to the delivery room at 29 Bahman Hospital over a two-year period (March 2022- April 2024) were included in the study (census sampling for the borderline group). For the control group, mothers with normal AFI were selected using matched sampling based on age, parity, and gestational age to correspond to the borderline group. The researcher reviewed the medical records of hospitalized mothers and selected controls who had undergone AFI ultrasound at the Radiology Center of 29 Bahman Hospital, matching on the three mentioned variables.

After pregnant women were admitted to the labor room, their details and obstetric history were reviewed and recorded. Following this, the specifications obtained during admission were examined and documented. Next, maternal perception of fetal movements was assessed as follows: If the mother feels 4 movements within 1 h, it is considered normal, and otherwise, it is considered reduced (Cunningham, 2020). Next, an NST was performed on all participants using a standardized device, Fetal monitoring TOITU- model MT516 was used in this study and only one midwife interpreted the results to ensure consistency. The interpretation of NST in this study was as follows: In fetuses at or beyond 32 weeks' gestation, the acceleration acme is $\geq$ 15 beats per minute (bpm) above the baseline rate, and the acceleration lasts $\geq$ 15 s but $<$ 2 min. Before 32 weeks, accelerations are defined as having a rise $\geq$ 10 bpm above baseline for $\geq$ 10 s (Cunningham, 2020). Then, biophysical profiles were performed for the research participants. A radiologist at the radiology center of 29 Bahman Hospital in Tabriz performed biophysical profile sonography using a single ultrasound machine. Five specific fetal biophysical variables include heart rate acceleration, breathing, movement, tone, and amnionic fluid volume. Using the biophysical profile, each normal variable is assigned a score of 2, and abnormal variables are given a score of 0. Thus, the highest score possible for a normal fetus is 10. Because fetal breathing and movement are episodic, 30 min are allotted to perform a BPP before a score of 0 is assigned to any component (Cunningham, 2020).

Before the study, participants were fully informed about its objectives and methods, the voluntary nature of their participation, the respect for their privacy, the confidentiality of their information, and their right to withdraw at any data collection stage. They were assured there was no need to write their name and surname, and all their information would remain confidential to the researcher. Informed written consent was obtained from each participant.

3.4. Data collection Tools and measurement

In this study, data were collected using a researcher-designed questionnaire comprising four main sections:

4 Demographic and Obstetric Characteristics: This section included information on the participants' demographic and obstetric characteristics such as age, education level, employment status, parity, gravidity, number of living children, number of miscarriages, number of fetal deaths, gestational age based on the last menstrual period (LMP), and gestational age based on the first ultrasound. (Cunningham, 2020).

5 Participant Admission Specifications: This section captured the specifications at the time of admission, including FHR, vital signs, vaginal examination during admission, uterine contraction status, condition of the amniotic sac at the time of admission, whether the amniotic sac was ruptured, and the duration from membrane rupture to delivery.

3. Delivery Outcomes: This part covered outcomes during delivery, including use of oxytocin, type of delivery; reasons for cesarean section; meconium-stained amniotic fluid; fetal distress; postpartum hemorrhage; and uterine atony in the first hour after birth.

6 Fetal Health Assessment Test Results: This section recorded the results of the fetal well-being tests, including maternal perception of fetal movements, NST, and BPP Score.

The questionnaire designed for this study was reviewed prior to implementation by ten faculty members from the Faculty of Medical Sciences at Islamic Azad University, Tabriz, to evaluate its content validity and item clarity. Based on their expert feedback, minor revisions were made to enhance the clarity, relevance, and alignment of the questions with the study objectives. These revisions included the removal of low-relevance items, rewording of certain questions for improved comprehension, merging of overlapping items, and the addition of questions aimed at better assessing women's status at the time of admission (such as the condition of the amniotic sac and the presence of uterine contractions). The finalized version of the questionnaire was then used as the primary tool for data collection.

3.5. Statistical analysis

The data were analyzed using SPSS software version 21. The normality of the distribution of quantitative data was assessed using skewness and kurtosis, which showed that all variables had a normal distribution. Descriptive statistics were utilized to create frequency tables and determine the study variables' central tendency and dispersion measures, providing a descriptive overview of the participants' characteristics. The independent *t*-test, Fisher's exact test, and Chi-square test were employed to compare the two groups. The results of univariate logistic regression were reported as a modified odds ratio (aOR) with a 95 % confidence interval (CI). $P < 0.05$ was considered statistically significant.

4. Results

4.1. Socio- demographic characteristics of the study participants

This study was conducted on 300 participants, including 150 with normal AFI and 150 with borderline AFI. The data analysis revealed no statistically significant differences between the two groups regarding demographic and obstetric characteristics ($p > 0.05$). The mean (SD) age of the mothers with normal AFI was 30.4 (5.8) years, while that of mothers with borderline AFI was 30.7 (5.1) years. Most women in both groups were homemakers (91.3 % in the normal AFI group and 93.3 % in the borderline AFI group). Nearly half of the mothers in the normal AFI group (49.3 %) and the borderline AFI group (42 %) had completed high school education. Close to half of the mothers in both groups were experiencing their first pregnancy (44.7 % in the normal AFI group and 45.3 % in the borderline AFI group). Slightly more than half of the mothers in the normal AFI (50.7 %) and borderline AFI groups (52 %)

were at 39 weeks of gestation based on their LMP. Approximately two-thirds of the mothers in the normal AFI (64 %) and borderline AFI groups (66 %) were at 39 weeks of gestation based on ultrasound findings (Table 1).

4.2. Admission specifications in normal and borderline AFI groups

An examination of the characteristics of the mothers at admission showed that FHR during admission was within the normal range in over 90 % of cases in both the normal AFI group (96.7 %) and the borderline AFI group (97.4 %), with no statistically significant difference between the two groups (p = 0.193). There were no statistically significant differences between the normal and borderline AFI groups regarding dilation (p = 0.402), effacement (p = 0.056), and station (p = 0.882) at the time of admission.

A review of the mothers' vital signs during admission indicated a statistically significant difference only in temperature between the two groups (p = 0.0001) and the mother's fever was higher in the borderline index group (44.7 %) than the normal index group (25.3 %); however, no significant differences were found in blood pressure (p = 0.853) or FHR (p = 0.736). The intensity of contractions was mild in most mothers in both groups (78.7 % in the normal AFI group and 87.3 % in the borderline AFI group), and there was a statistically significant association between the two groups (p = 0.048). Although contractions at the time of admission were more frequent in the normal AFI group (58 %) compared to the borderline AFI group (48.7 %), the difference was not statistically significant (p = 0.106). No significant differences were observed between the two groups regarding the rupture of membranes at the time of admission (p = 0.200) or the nature of the membrane rupture (p = 0.311). The variables and the Amniotic Fluid Index were included in the univariate logistic regression model. The results showed that in women with normal AFI, the body temperature value below 37 was 5 times more likely than in women with a borderline AFI (OR = 5.64; 95 % Cl: 3.00 to 10.71; p = 0.0001). Also, normal contractions were 2 times more likely in the normal AFI group than in the borderline AFI group (OR = 1.87; 95 % Cl: 1.01 to 10.73.47; p = 0.048) (Table 2).

Table 1
Comparison of demographic and obstetric characteristics in normal and borderline amniotic fluid index (AFI) groups.

Characteristic	Normal AFI (n = 150)	Borderline AFI (n = 150)	P value
	Number (%)	Number (%)	
Age (Year)			0.080†
18–26	38(25.3)	27(18.0)	
27–34	64 (42.7)	83 (55.3)	
35–42	48 (32.0)	40 (26.7)	
Job			0.350†
Housewife	137 (91.3)	140 (93.3)	
Employed	13 (8.7)	10 (6.7)	
Education			0.690†
Illiterate/ Elementary school	24 (16.0)	30 (20.0)	
Secondary school	31 (20.7)	32 (21.3)	
High school diploma	74 (49.3)	63 (42.0)	
University	21 (14.0)	25 (16.7)	
Gravidity			0.723†
1	67 (44.7)	68 (45.3)	
2	50 (33.3)	51 (34.0)	
≥3	33 (22.0)	31 (20.7)	
Parity			0.998†
0	73 (48.7)	74 (49.3)	
1	60 (40.0)	60 (40.0)	
≥2	17 (11.3)	16 (10.6)	
Number of children			0.525†
1	74 (49.3)	75 (50.0)	
2	60 (40.0)	63 (42.0)	
≥3	16 (10.6)	12 (8.0)	
Number of fetal deaths			0.428†
0	148 (98.7)	145 (96.7)	
1≤	2 (1.3)	5 (3.3)	
Number of abortion			0.906†
0	122 (81.3)	124 (82.7)	
≥1	28 (18.7)	26 (17.3)	
Gestational age (LMP§)			0.778†
≤37	17 (11.3)	20 (13.3)	
38	53 (35.3)	51 (34.0)	
39	76 (50.7)	78 (52.0)	
Mean (SD)	38.36 (0.82)	38.34 (0.84)	0.832*
Gestational age (Ultrasound)			0.676†
≤37	22 (14.7)	19 (12.7)	
38	32 (21.3)	32 (21.3)	
39	96 (64.0)	99 (66.0)	
Mean (SD)	38.44 (0.88)	38.49 (0.84)	0.616*

*Independent *t*-test; †Chi-square test, § Last Menstrual Period.

Table 2
Comparison of admission specifications between women with normal AFI* and borderline AFI based on the univariate logistic regression model.

Characteristic	Normal AFI (n = 150)	Borderline AFI (n = 150)	OR (95 % CI)*	P value
	Number (%)	Number (%)		
FHR				†
Normal	145 (96.7)	146 (97.4)	0.73 (0.21–3.01)	
Abnormal	5 (3.3)	4 (2.6)	1	
Dilatation				
≤4cm	134 (89.3)	126 (84.0)	0.63 (0.32–1.23)	0.177†
>4cm	16 (10.7)	24 (16.0)	1	
Effacement				†
≤50 %	137 (91.3)	132 (88.0)	0.70 (0.33–1.48)	
>50 %	13 (8.7)	18 (12.0)	1	
Station				
−3	92 (61.3)	98 (65.3)	1.19 (0.74–1.90)	0.472†
>-2	58 (38.7)	52 (34.7)	1	
Blood pressure				‡
>140/90	133 (88.7)	130 (86.7)	0.94 (0.49–1.80)	
≥140/90	17 (11.3)	20 (13.3)	1	
Body temperature				
≤37	112 (74.7)	83 (55.3)	5.64 (3.00–10.71)	0.0001†
>37	38 (25.3)	67 (44.7)	1.32 (0.78–2.32)	0.290
PR				
70–100	150 (100.0)	149 (99.3)	0(0–0)	0.100†
>100	0 (0)	1 (7.0)	1	
Contractions at admission	87 (58.0)	73 (48.7)	1.46 (0.92–2.30)	0.106‡
Contraction intensity				
Mild	118 (78.7)	131 (87.3)	1.87 (1.01–3.47)	0.048‡
Normal	32 (21.3)	19 (12.7)	1	
Amniotic sac rupture at admission	13 (8.7)	20 (13.3)	0.62 (0.29–1.29)	0.200‡
Cause of amniotic sac rupture				
Spontaneous	40 (26.7)	48 (32.0)	0.77 (0.47–1.27)	0.311‡
Amniotomy	110 (73.3)	102 (68.0)		
Duration of rupture of membranes until delivery				
1–12 h	113 (75.3)	97 (64.6)	0.89 (0.46–1.75)	0.745†
≥13 h	23 (15.3)	21 (14.0)	1	

† Chi-square test; ‡ Fisher's exact test * Adjusted Odds Ratio (95% Confidence Interval).

4.3. Fetal health assessment test results

Delivery outcomes between women with normal AFI and borderline AFI showed that Oxytocin was used during labor in 68 % of women with normal AFI and 78.8 % with borderline AFI, indicating a statistically significant difference between the two groups (p = 0.038). Regarding the type of delivery, 13 (8.7 %) women with normal AFI and 31 (20.7 %) women with borderline AFI had a cesarean section, showing a significant difference in delivery type between the two groups (p = 0.005). There was no statistically significant difference the reason for cesarean section (p = 0.627), the need for episiotomy (p = 0.124), fetal distress (p = 0.777), meconium-stained amniotic fluid (p = 0.262), postpartum hemorrhage (p = 0.456), and uterine atony within the first hour after delivery (p = 0.404). The variables and the Amniotic Fluid Index were included in the univariate logistic regression model. The results showed that in women with borderline AFI, use of oxytocin was almost 2 times more likely than in women with a normal AFI (OR = 1.73; 95 % Cl: 1.03 to 2.92; p = 0.038). Additionally, results showed in women with borderline AFI, type of cesarean delivery almost 3 times more likely than in women with a normal AFI (OR = 2.63; 95 % Cl: 1.34 to 5.17; p = 0.005) (Table 3).

4.4. Delivery outcomes and relationship between in normal and borderline AFI groups based on the univariate logistic regression model

An analysis of the fetal health assessment test results revealed that a reduction in perceived fetal movements by the mother was reported by 35 mothers (23.3 %) in the normal AFI group and 46 mothers (30.7 %) in the borderline AFI group, with a statistically significant difference observed between the two groups (p = 0.0001). However, no statistically significant differences were found between the groups in the results of the NST (p = 0.324) and BPP (p = 0.817) tests. In both groups, over 80 % of mothers (84 % in the normal AFI group and 81.3 % in the borderline AFI group) had a reactive non-stress test. Regarding interpreting the biophysical profile test results, around half of the cases in the normal AFI group (48 %) and the borderline AFI group (49.3 %) scored a ten. Additionally, 50 % of mothers in the normal AFI group and 42.7 % in the borderline AFI group scored an eight. The rates of deceleration (p = 0.999), tachycardia (p = 0.703), and bradycardia (p = 0.137) were all below 3 % in both groups, with no statistically significant differences observed The variables and the Amniotic Fluid Index were included in the univariate logistic regression model. The results showed that in women with borderline AFI, Maternal perception of decreased fetal movement was 7 times more likely than in women with a normal AFI (OR = 7.43; 95 % Cl: 4.4 to 12.4; p = 0.0001) (Table 4).

Table 3
Delivery outcomes and relationship between women with normal AFI and borderline AFI based on the univariate logistic regression model.

Characteristic	Normal AFI (n = 150)	Borderline AFI (n = 150)	OR (95 % CI)*	P value
	Number (%)	Number (%)		
Use of oxytocin	102 (68.0)	118 (78.7)	1.73 (1.03–2.92)	0.038‡
Type of delivery				
Cesarean section	14 (9.4)	32 (21.3)	2.63 (1.34–5.17)	0.005†
Vaginal delivery	136 (90.6)	118 (78.6)	1	
Vaginal delivery				
Episiotomy/ Rupture	112 (74.7)	92 (61.3)	0.76 (0.41–1.41)	0.381†
Without any rupture or episiotomy	24 (16.0)	26 (17.3)	1	
Episiotomy	81 (54.0)	70 (46.7)	0.74 (0.47–1.17)	0.204‡
Fetal distress	7 (4.7)	6 (4.0)	0.85 (0.28–2.59)	0.777‡
Meconium-stained amniotic fluid	8 (5.3)	13 (8.7)	1.68 (0.68–4.19)	0.262‡
Postpartum hemorrhage	10 (6.7)	7 (4.7)	0.68 (0.25–1.85)	0.456‡
Uterine atony in the first hour after birth	8 (5.3)	10 (6.7)	1.27 (0.49–3.31)	0.404‡
Reason for the cesarean section				
Pelvic stenosis/ Lack of labor progress	6 (4.0)	9 (6.0)	0.50 (0.13–1.91)	0.627†
Abnormal FHR/ Meconium-stained amniotic fluid	7 (4.7)	21 (14.0)	1	

Amniotic Fluid Index; †Chi-square test; ‡ Fisher's exact test *Adjusted Odds Ratio (95% Confidence Interval).

5. Discussion

The results of the study indicated that the perception of decreased fetal movements by the mothers was more prevalent among those with borderline AFI compared to the normal AFI group. A survey by Komariah et al. (2023) showed that parity and maternal underlying conditions such as diabetes and hypertension did not affect the mother's perception of fetal movement. However, oligohydramnios strongly correlated with the mother's perception of fetal movement (Komariah and Wahyuni, 2023). Similarly, studies by Saxen et al. (2020) and Gagare (2022) found that oligohydramnios in mothers was associated with reduced fetal movement (Saxena et al., 2020, Gagare et al., 2022). Einspieler et al. (2021) also reported that in pregnancies with reduced amniotic fluid, fetal movement decreased in 64 % of cases (Einspieler et al., 2021). Furthermore, Sheykh et al. (2014) showed that fetal movements gradually reduced as the AFI decreased from normal to oligohydramnios to the extent that mothers with severe oligohydramnios did not perceive any fetal movement (Sheikh et al., 2014). Since we could not access studies examining maternal perception of fetal movements in borderline AFI, we had to reference studies addressing fetal movements in oligohydramnios. Given the higher prevalence of decreased fetal movements in mothers with borderline AFI, it is essential

Table 4
Comparison of fetal health assessment tests outcomes between women with normal AFI* and borderline AFI based on the univariate logistic regression model.

Characteristic	Normal AFI (n = 150)	Borderline AFI (n = 150)	OR (95 % CI) *	P value
	Number (%)	Number (%)		
Maternal perception of fetal movement				
Normal	115 (76.7(	104 (69.3)	7.43 (4.4–12.4)	0.0001‡
Reduced	35 (23.3)	46 (30.7)	1	
NST interpretation				
Reactive	126 (84.0)	122 (81.3)	0.76 (0.41–1.41)	0.324‡
Non Reactive	24 (16.0)	28 (18.7)	1	
Decelerartion	0 (0)	3 (2.0)	0(0–0)	0.999‡
Tachycardia	3 (2.0)	4 (2.7)	0.74 (0.16–3.4)	0.703‡
Bradycardia	1 (0.7)	5 (3.3)	0.19 (0.02–1.69)	0.137‡
Biophysical profile				
10	72 (48.0)	74 (49.3)	0.95 (0.60–1.50)	0.817†
≤8	78 (52.0)	76 (50.7)	1	

†Chi-square test; ‡ Fisher's exact test *Adjusted Odds Ratio (95% Confidence Interval).

to advise these mothers to record daily fetal movement counts and promptly seek medical care if a reduction in movements is observed.

The results of the NST indicated that over 80 % of mothers in both groups had an active NST, and there was no statistically significant difference between the two groups. Shweta et al. showed in their study that there was a statistically significant relationship between the NST results between the two groups of cases and controls, and in the case group, 40 % of the NST results were reactive and 60 % were non-reactive. In the control group, 98 % of the infants had reactive NST and only 2 % had non-reactive NST(Shweta et al., 2023). The results of this study were not consistent with our study, and the rate of non-reactive NST in the borderline AFI group was lower in our study.

Studies by Vasanthamani et al. (2020) and Premalatha (2020) have shown that oligohydramnios with an active NST have generally favorable labor and neonatal health outcomes. However, neonatal complications tend to increase when a non-reactive NST accompanies oligohydramnios (Vasanthamani et al., 2020, Premalatha and Bhaskar, 2020). Sekhon et al. (2021) demonstrated abnormal FHR in mothers with true oligohydramnios (Sekhon et al., 2021). Additionally, Parsad et al. (2020) indicated that borderline AFI is associated with abnormal NST results (Prasad and Nair, 2020). In Vijayasree's study of 100 pregnant women with borderline amniotic fluid index, only 9 % of women had non-reactive NST. In our study, 18.7 % of women had non-reactive NST, Which was higher than in Vijayasree's study (Vijayasree, 2023).

FHR upon admission was normal in over 90 % of cases in the normal AFI group (96.7 %) and the borderline AFI group (97.4 %), with no statistically significant difference between the two groups. Tithy et al. (2022) found that FHR was normal in cases of borderline AFI but abnormal in severe oligohydramnios (Tithy, 2022). Similarly, Zilberman et al. (2022) reported a significant irregularity in FHR only in cases of severe oligohydramnios (Zilberman Sharon et al., 2022).

The results concerning labor outcomes indicated a statistically significant difference between the two groups regarding using oxytocin to induce labor. In 68 % of women with normal AFI and 78.8 % of women with borderline AFI, oxytocin was used during labor. Yin et al. (2018) found that the success of labor induction with oxytocin was higher in women with borderline AFI (Yin et al., 2018). Conversely, Rathod et al. (2017) found that labor induction in cases with borderline AFI compared to instances with normal AFI in term pregnancies showed no significant difference in the induction-to-delivery interval (Rathod and Samal, 2017). Zhang et al. (2022) also reported that the success rate of labor induction and natural childbirth in women with borderline AFI, except in cases of high maternal and fetal weight, was similar to that of women with normal AFI (Zhang et al., 2022). Studies have reported different results regarding the use of oxytocin and its success, suggesting the need for further studies with larger sample sizes.

The analysis of the type of delivery showed that 8.7 % of women with normal AFI and 20.7 % of women with borderline AFI had cesarean deliveries. Yadav et al. (2021) showed that borderline AFI were more associated with cesarean sections among primiparous women (Yadav et al., 2021). Yin et al. (2018) reported a higher rate of cesarean section compared to vaginal delivery in the borderline AFI group, attributing it to higher fetal weight and maternal blood pressure during pregnancy (Yin et al., 2018). The results of these studies align with our study regarding the increased rate of cesarean sections in the borderline AFI group.

6. Limitations of the study

One of the limitations of the present study was the lack of measurement of the amniotic fluid volume using the MVP on ultrasound. Using the AFI can lead to increased oligohydramnios detection and labor induction for oligohydramnios without necessarily improving perinatal outcomes. Therefore, using the single deepest vertical pocket (SDP) with AFI is recommended to estimate amniotic fluid volume accurately (Kehl et al., 2016, Cunningham, 2020). Given that this study was conducted on term pregnancies, it is suggested that future research includes all mothers with borderline AFI regardless of gestational age. Given the insufficient evidence regarding the potential risks associated with borderline amniotic fluid, the existence of conflicting results in studies, the uncertainty of the importance of further fetal health assessment tests and the importance of maternal hospitalization to maintain or terminate pregnancy in cases of borderline AFI, it is recommended that further studies with larger sample sizes be conducted.

The majority of studies conducted on pregnant women with borderline AFI have evaluated labor and neonatal outcomes and have not examined fetal health assessment tests. Therefore, one of the strengths of the present study is the evaluation of all three main fetal health assessment tests (fetal movement reduction by the mother, NST, and BPP) in this study.

7. Conclusion

The results of fetal health assessments in cases of borderline AFI were similar to those in cases with normal AFI. Therefore, currently, there is insufficient evidence to support the use of excessive fetal health testing in cases of borderline AFI. It is recommended that such cases be managed similarly to those with a normal AFI. However, since a reduction in maternal perception of fetal movements was more prevalent among mothers with borderline AFI compared to those with a normal index, it is advisable to recommend daily fetal movement counts to mothers with a borderline AFI and to instruct them to seek hospital care if there is a reduction in fetal movements.

8. Authors' contributions

SN, ZP, and FF are involved in the conception and design, acquisition of data, and drafting of the manuscript. MM (corresponding author) was involved in the conception and design, acquisition of data, blinded analysis of the data, interpretation of data, and writing this manuscript. All authors gave their final approval of this version to be published.

CRediT authorship contribution statement

Somayyeh Naghizadeh: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Zahra pourmohammad:** Investigation. **Farnaz Faroughi:** Writing – original draft, Software, Investigation, Conceptualization. **Mojgan Mirghafourvand:** Writing – review & editing, Visualization, Validation, Supervision, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Ethics approval and consent to participate

All the procedures performed in this study that involved human subjects were in full compliance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval was obtained from the ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1400.003) to conduct the research. Written informed consent was submitted by all the participants before enrolment in the study.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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