

## BIOPHYSIT: A Novel Biophysical Profile Database for Fetal Stress Measurement in High-Risk Pregnancies

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Pregnancy is a time of change. Stress during pregnancy can increase the chances of having a premature baby or a low birth weight baby. Any unusual changes in the heart rate of the baby in the uterus can be examined using Electronic fetal monitoring (EFM). Over the past decades, enormous devices and methods have been developed for EFM. Few devices are invasive and few are non-invasive in nature, larger in size, and high in cost. The main parameter needed to be analyzed during pregnancy is the stress in the fetus as well as the mother. For fetal stress monitoring, two main tests have been used such as CTG (Cardiotocography) and BPP (Biophysical Profile). The BPP test is very important in determining whether the fetus is in a suspicious or normal condition based on a specific BPP score. However, BPP is still used as a visualization method to assess the condition of the fetus. As a result, a quantitative analysis of the BPP parameters is required. But still, now there is no specific BPP database for evaluating the condition of the fetus. So, a novel database for Biophysical profile is proposed named "BIOPHYSIT", which is used to analyze the health condition of the fetus using various BPP parameters.

**Keywords:** Biophysical profile; Electronic fetal monitoring; Fetal stress; Fetal Movement; Fetal Heart Rate; Uterine Contraction.

Fetal monitoring is commonly used to measure fetal surveillance, but it is essentially a winding path to determining fetal well-being or fetal oxygenation sufficiency<sup>1,2,3</sup>. The primary goal of fetal monitoring during pregnancy is to ensure a healthy baby is delivered. Any unusual changes in the baby's heart rate in the uterus can be detected using electronic fetal monitoring (EFM). Initially, direct monitoring of fetal heart sounds can be examined with a stethoscope which is placed on the maternal abdomen. EFM was used for complex pregnancies in the early stages of 1965. However,

as technology and ease of use improved, this EFM<sup>4</sup> began to be used in all pregnancies, including low-risk pregnancies. Some of the complex events in the uterus can have a negative neonatal outcome. Inadequate fetal monitoring can result in fetal death. The risk of neonatal death in developing countries, particularly India<sup>5</sup>, is six times that of developed countries, and more than eight times that of less-developed countries. Figure 1 depicts data on the fetal mortality rate in India from 2009 to 2019. If it goes undetected, it has a significant impact on neonatal mortality.

Due to advancements in medical technology, few devices are available for providing reasonable information about the fetus during its intrauterine life that is reliable. There are several important parameters for monitoring the status of the fetus. Among those, Fetal Heart Rate (FHR)<sup>6</sup> gives the most important information and it is a commonly used parameter. FHR and other parameters can now be monitored using a variety of measuring, recording, and analyzing instruments. Ultrasound, Doppler ultrasound, fetal cardiotocography (FCTG), fetal electrocardiography (FECG)<sup>7</sup>, and fetal magnetocardiography are some of the tests available. Many methods and devices for monitoring fetal health during the first trimester and during labor were reviewed in this study. Monitoring the baby's health condition in the uterus during pregnancy is often undertaken using a cardiotocography (CTG)<sup>8</sup> machine.

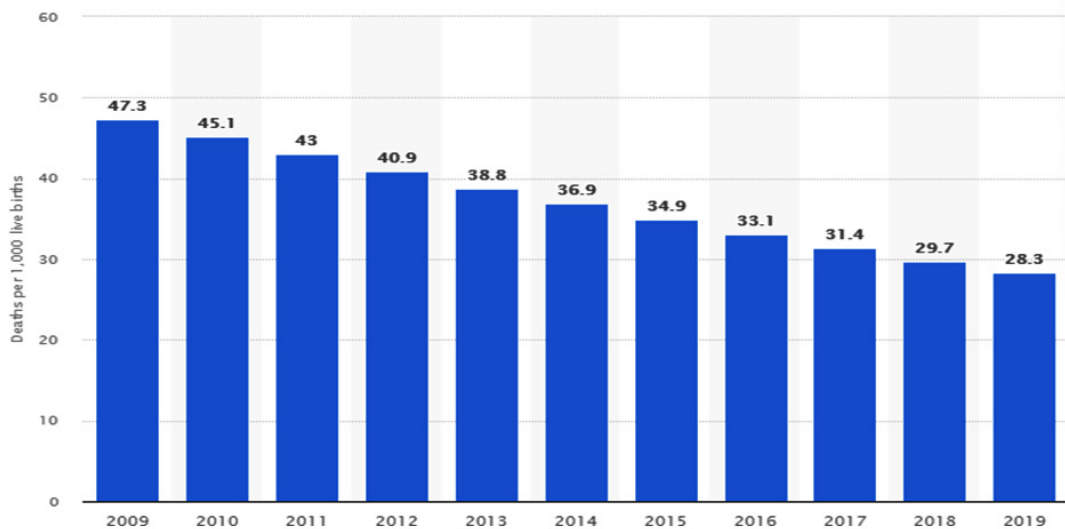
Monitoring fetal movements has thus been proposed as a useful addition to predicting fetal abnormality. This is because a decrease in fetal movement can result in the death of the baby. Fetal movement is thought to be less frequent if the oxygen supply to the baby through the placenta is insufficient. To view fetal movements, the biophysical profile (BPP)<sup>9</sup> and the modified biophysical profile (MBPP) have been introduced. The ultrasound test is used in the Biophysical Profile to assess 1) fetal body movement, 2) fetal tone movement, 3) fetal breathing movement, and

4) amniotic fluid volume that surrounds the baby. A modified BPP is sometimes used first, involving only the CTG trace and the amniotic fluid volume. If there is a chance that abnormality conditions will occur, the full BPP is used. The BPP and MBPP<sup>10</sup> were compared to conventional CTG monitoring on pregnancy in high-risk pregnancies in this review of trials. CTG and BPP tests are used to monitor fetal conditions during the non-stress test. This paper is organized as follows: Section I explains the details about fetal stress, its occurrence, and the methods for measuring fetal stress. The subsequent section explains the Analysis of Fetal stress using CTG and BPP. Section III detailed the Overview of the Existing Fetal Monitoring Device. Section IV explains the proposed fetal stress monitoring device. Section V summarizes the review and gives a comparative analysis.

## MATERIAL AND METHODS

### Analysis of Fetal stress using CTG and BPP CTG Test

The Cardiotocography (CTG) machine<sup>11</sup> will measure the heart rate of the baby. It also monitors uterine contractions at the same time. It is used to observe the baby for any signs of stressful conditions both before and during the birth (antenatal). Doctors can see how the baby is coping by examining various features of the baby's heart rate. The equipment used to perform a CTG



**Fig. 1.** Fetal deaths per 1000 live birth in India over 2009-2019 ©Statista 2021 [1]

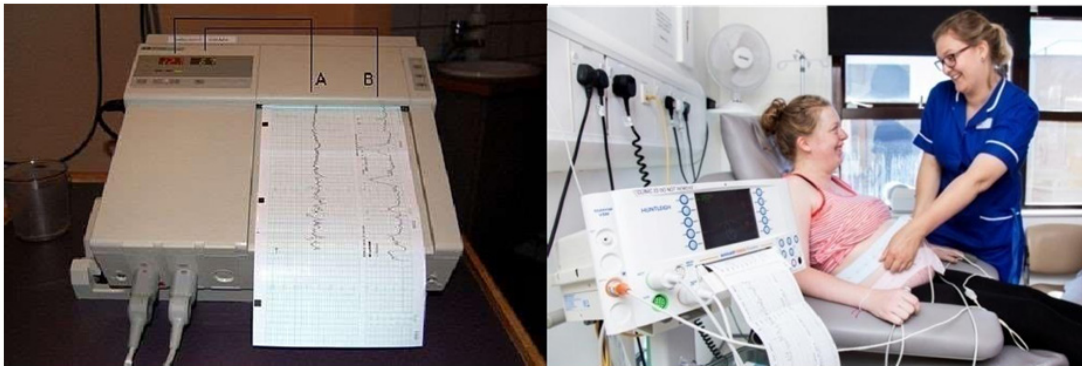
is depicted in Figure 2. It is usually placed beside the bed while the pregnant lady is being monitored. External CTG tests are most commonly performed. The equipment used to monitor the baby's heartbeat using an electrode placed on the mother's abdomen is referred to as this. The mother's abdomen is wrapped in an elastic belt.

The midwife may apply jelly to the mother's abdomen to help get a strong signal. The CTG belt is connected to a machine that decodes the FHR and UC signals<sup>12</sup> produced by the plates. The foetal heart rate is represented by a beating or pulsing sound produced by the CTG machine. The machine also prints out the FHR over a specified time period. If you have CTG during labour, you may be asked to press a button on the machine every time the baby moves. The CTG will only monitor the baby's heart rate because the person under observation will not be having contractions

at this time. Internal monitoring can be used if an FHR signal cannot be found using the external monitor during labour. Internal monitoring makes use of the electrode. After being inserted through the vagina, this is placed on the baby's scalp. If a female is pregnant with twins (or multiples), the electrode can only be used on the baby closest to the womb's neck. Furthermore, internal monitoring can only be used if the baby is to be delivered head first. Internal monitoring will not function in the case of a breech (bottom or foot first) presentation. CTG monitoring employs a type of ultrasound known as a Doppler probe. Because this type of ultrasound can measure moving structures, it is useful for monitoring foetal heart rate.

#### **Bio Physical Profile Test**

Figure 3 depicts the Biophysical Profile test, which is used to assess the baby's health. It detects fetal muscle tone and movement. It is also



**Fig. 2.** Cardiotocography (CTG) machine [2]



**Fig. 3.** Ultrasound scan for BPP test [3]

used to determine how quickly the FHR accelerates during fetal movement and the amount of amniotic fluid that protects your baby in the womb. The BPP<sup>13</sup> is both non-hazardous and non-invasive. The procedure takes approximately 30 minutes. An ultrasound is included as part of the BPP. This monitors fetal movement and measures amniotic fluid levels in the womb. The mother is asked to lie on her back while an ultrasound technician holds the wand against her belly. A non-stress test that monitors FHR for about 20 minutes is also included in the BPP. The results of the BPP test are added together to form a total BPP score, which includes the heart rate, breathing movement, body movement, muscle tone movement and level

of amniotic fluid. A score of 8 to 10 indicates that your baby is healthy. If the Score is less than eight, usually retest is suggested. If the score is less than 5, it may indicate that the baby is under stress. As a result of the above, the doctor may recommend early delivery. Some women have BPP testing earlier or later in their pregnancy.

From Table 1, it's known that the CTG and BPP test helps to measure the baby's health condition throughout the gestational period. For fetal stress monitoring, various existing devices are available. Few devices are invasive and few are non-invasive in nature, larger in size, and high in cost. Medical devices such as fetal Monitor – LPM 703 (Life Plus), BPL FM9852, Bistros BT350 Fetal

**Table 1.** Comparative analysis of CTG and BPP test

No	Non-Stress Test	Parameters	Time Duration	Advantages	Disadvantages
1.	Cardiotocography (CTG) test	<ul style="list-style-type: none"> <li>• Fetal Heart Rate (FHR)</li> <li>• Uterine Contractions (UC)</li> </ul>	<ul style="list-style-type: none"> <li>• Most commonly at Third trimester of the pregnancy.</li> <li>• CTG records the FHR and UC for about 30 minutes.</li> </ul>	<ul style="list-style-type: none"> <li>• FHR and UC can be monitored at the same time.</li> <li>• Smooth HR in the timeline.</li> <li>• Reduce rates of seizure in newborn.</li> <li>• Rather robust and reliable.</li> </ul>	<ul style="list-style-type: none"> <li>• Prevent Mother from Moving.</li> <li>• Unable to change position.</li> <li>• Ultrasound Radiation.</li> <li>• No information about BTB (Beat-to- Beat) variability.</li> </ul>
2.	Bio Physical Profile test (BPP)	<ul style="list-style-type: none"> <li>• Fetal Heart Rate</li> <li>• Fetal Breathing Movement</li> <li>• Fetal Tone Movement</li> <li>• Fetal Body Movement</li> <li>• Amniotic Fluid</li> </ul>	<ul style="list-style-type: none"> <li>• About 30 min</li> <li>• <math>\geq 1</math> episode lasting <math>&gt;30</math>seconds</li> <li>• <math>\geq 1</math> episode of extensions (limb or trunk) with return of flexion.</li> <li>• <math>\geq 3</math> discrete body/limb movements</li> <li>• <math>\geq 1</math> pocket measuring 2 cm in two perpendicular planes</li> </ul>	<ul style="list-style-type: none"> <li>• This is Non-invasive and helps to evaluate the fetal conditions</li> <li>• The false negative rate of a normal BPP is less than 0.1%.</li> </ul>	<ul style="list-style-type: none"> <li>• Ultrasound Radiation.</li> <li>• It is a long procedure and takes more time to evaluate the fetal condition.</li> <li>• BPP test is not cost effective.</li> </ul>

Monitor CTG Machine, etc., measure FHR, Fetal Movements, and Uterine Contractions only. By analyzing these parameters, the fetal conditions are classified as Normal/ Suspicious/ Pathological conditions. By taking this into consideration, a new device must be proposed to analyze the fetal health condition using various parameters like a uterine contraction, Fetal Heart Rate, Maternal Heart Rate, and BPP parameters. In the existing devices, only a few parameters have been calculated, it is high in cost and has poor accuracy. To achieve

high accuracy in the proposed device, a bunch of Biophysical profile databases is needed for the analysis of fetal health conditions. For that, a benchmark Biophysical profile database is proposed and named as BIOPHYSIT database. With the help of this BIOPHYSIT database, a new fetal stress monitoring device can be proposed in the future.

**Bio Physical Profile**

A biophysical profile (BPP) test<sup>14</sup> assesses the fetus's health during pregnancy. A non-stress

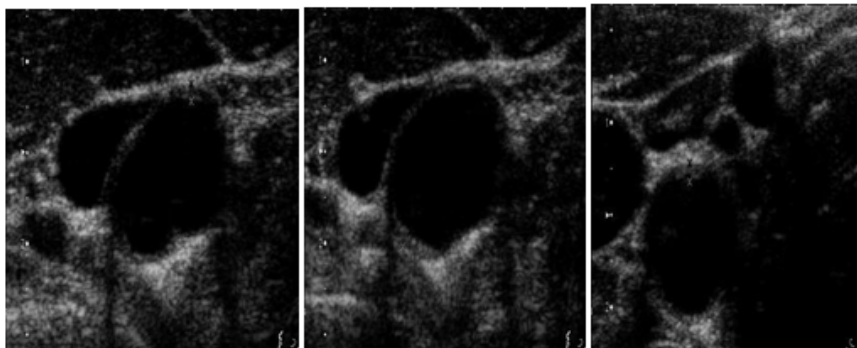


Fig. 4. BIOPHYSIT AF (Amniotic fluid)

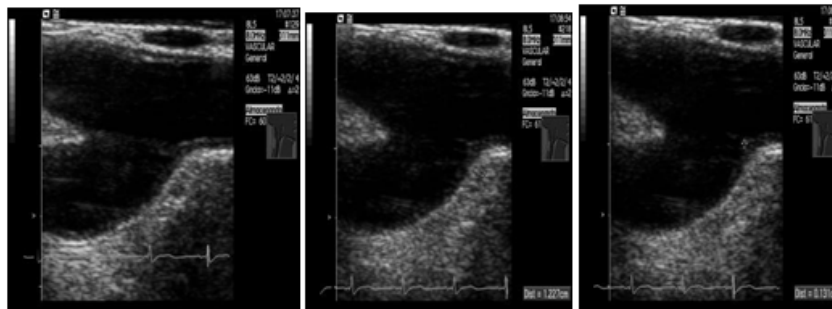


Fig. 5. BIOPHYSIT FBM (Fetal Body movement)

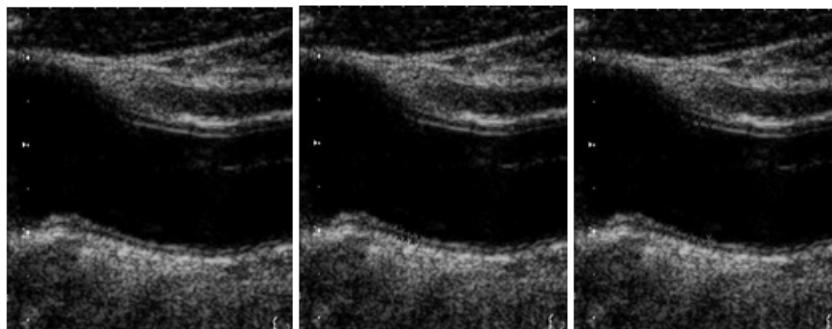


Fig. 6. BIOPHYSIT FBRM (Fetal breathing movement)

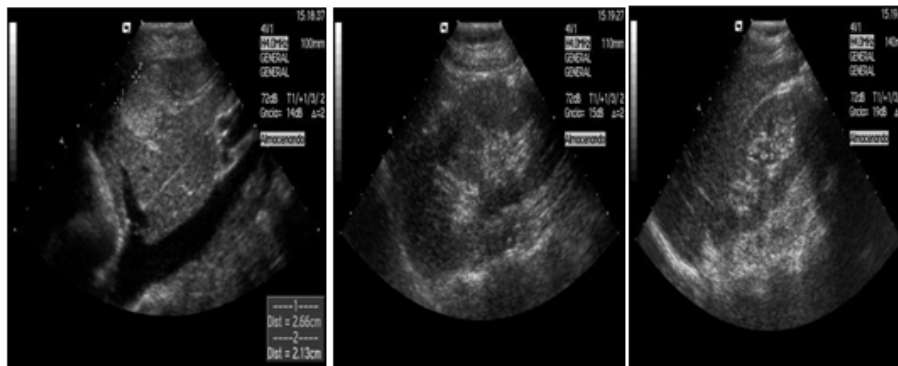
test with electronic fetal heart monitoring and fetal ultrasound may be included in a BPP test. The baby's heart rate, muscle tone movement, breathing movement, and amniotic fluid level in the womb are all assessed by the BPP. A BPP is typically performed in the third trimester of pregnancy. If there is a chance that the baby will have problems during the pregnancy, a BPP may be performed as early as from 32 to 34 weeks (high-risk pregnancy). Some women with high-risk pregnancies may have a BPP test every week or twice a week during the third trimester. It is considered normal to have a normal fluid index<sup>15</sup> score of 10/10 or 8/10.

In the Fetal body movement<sup>16</sup>, fetal movements have their own time-of-day and sleep-activity rhythm. The baby kicks the most during light sleep in the last month or so of pregnancy. The fetus may move less during its sleep cycles. Similarly, in healthy mammalian fetuses, Fetal breathing movement occurs episodically. FBMs

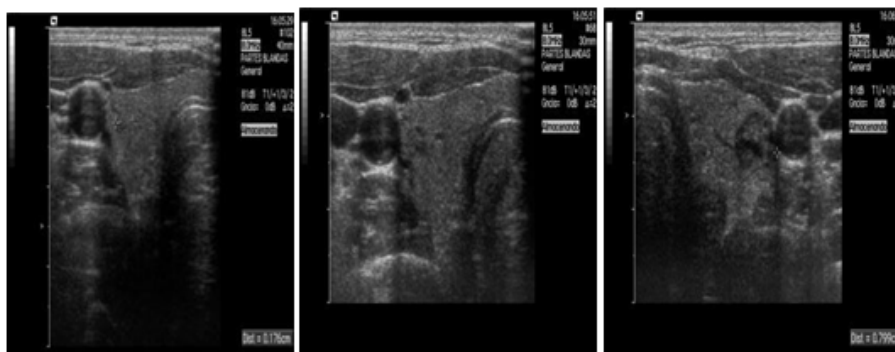
are rhythmic diaphragmatic contractions that are centrally organized; similar to postnatal breathing, but they may also involve other skeletal muscles such as those of the chest wall and upper respiratory tract. In Amniotic Fluid Level, AFI between 8 and 18 is considered normal. From week 20 to week 35, when amniotic fluid begins to decrease in preparation for birth, the median AFI level is around 14. Oligohydramnios is defined as an AFI of 5-6. It refers to an ultrasound grading system of the placenta based on its maturity in Placental Grading<sup>17</sup>. This has the greatest impact on the extent of calcifications. Placental grading has been phased out of obstetric practice in some countries due to a weak correlation with adverse prenatal outcomes. Similarly, the ability to flex and extend an arm or leg is measured in the Fetal Tone Movement by counting quick, jerky movements.

#### **BIOPHYSIT Database**

The lack of a suitable database for further research and development in the biomedical field



**Fig. 7.** BIOPHYSIT PG (Placental Grading)



**Fig. 8.** BIOPHYSIT FT (Fetal tone movement)

and in healthcare applications inspired us to create a new and uncommon database, which we named the BIOPHYSIT database. This BIOPHYSIT database was designed primarily to serve as a resource for fetal stress measurements. BIOPHYSIT was created using ultrasound fetal movement images collected from a popular and standard scan center in Chennai. The fetal movement video is recorded for 2-5 minutes and used to evaluate the health of the fetus. Ultrasound is used to record the sequences.

This database consists of two ultrasound video sequences, which are then converted into planes. The plane has 300 ultrasound scan images, which are collected from 50 female subjects. A fetal biophysical profile is a prenatal test used to assess the health of a baby. The test combines fetal heart rate monitoring and fetal ultrasound to determine a baby’s heart rate, breathing movement, fetal movements, muscle tone movement, and amniotic fluid level. A sample BIOPHYSIT AF (Amniotic fluid), is shown in Figure 4. Similarly, the sample BIOPHYSIT FBM (Fetal Body movement) is shown in Figure 5. Then, the sample BIOPHYSIT FBRM (Fetal breathing movement) is discussed in Figure 6. The sample BIOPHYSIT PG (Placental Grading) is shown in Figure 7. The sample

BIOPHYSIT FT (Fetal tone movement) is shown in Figure 8.

**Details of Construction and Composition of the database**

The BIOPHYSIT database is built from ultrasound scan images of Indians. A total of 300 ultrasound images were collected from the 50 female subjects. All of the images are manually cropped and it is saved as image files in ‘PNG’ format. The BPP measurement plots for each subject’s ultrasound scan images have been provided in the same png format. The database is divided into five categories: BIOPHYSIT AF, BIOPHYSIT FBM, BIOPHYSIT FBRM, BIOPHYSIT PG, and BIOPHYSIT FT. The main database, BIOPHYSIT-DB, contains all of the scan images, and the sample BIOPHYSIT AF contains Amniotic fluid images. Similarly, images of Fetal Body movement can be found in the sample BIOPHYSIT FBM. The sample BIOPHYSIT FBRM contains fetal breathing movement images, while the sample BIOPHYSIT PG contains Placental Grading images. Fetal tone movement images are included in the sample BIOPHYSIT FT.

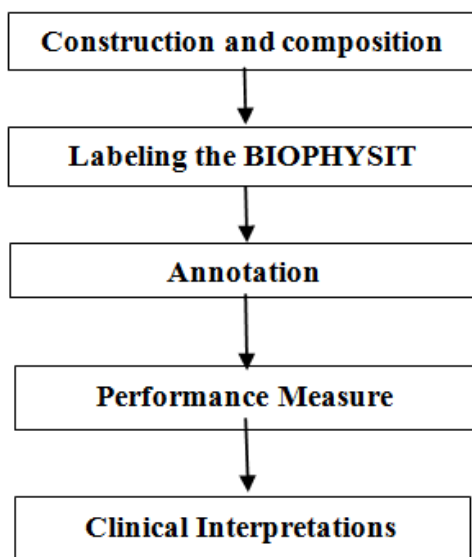
**Labeling the BIOPHYSIT dataset**

All of the images in the BIOPHYSIT database are perfectly labeled for the accessibility of researchers. The subject ID, BPP, and gender of the subject can be easily identified from the label. Images of ultrasound scans are obtained for each subject. The label for an ultrasound scan image, for example, is BIOPHYSIT AF 010.png and BIOPHYSIT PG 023. png. In the first module, BIOPHYSIT is an image of a fetal ultrasound scan, AF is an image of amniotic fluid in a female subject, and 010 is the subject ID. BIOPHYSIT PG denotes an ultrasound image, PG denotes a female subject’s placental grading image, and 023 is the subject ID in the latter case. Similarly, BIOPHYSIT FBM 033.png and BIOPHYSIT FBRM 002.png are ultrasound images of female subjects’ fetal body movements with subject IDs 033 and 002, respectively.

**Annotation**

BIOPHYSIT provides detailed annotation by carefully analyzing each ultrasound scan image. We manually annotated the following attributes for each fetal image.

**Biological data of the subject**



**Chart 1.** Basic structure of BIOPHYSIT database



- Name of the subject
- Age
- Gender
- Height (cm)
- Weight (kg)
- CTG Recordings
- UC recordings
- Amniotic fluid level
- Fetal Body Movement
- Fetal Breathing Movement

- Placental Grading
- Fetal Tone Movement

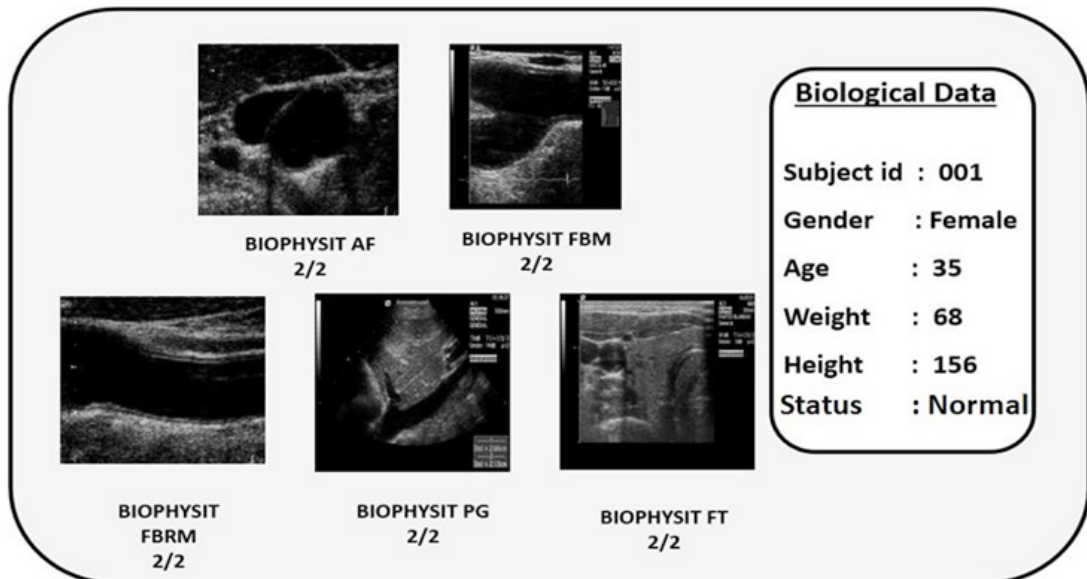
**Performance Measure**

Table 2 details the Bio physical profile score values.

Non-conclusive studies should prompt a medical investigation into the cause and preparation of the mother and fetus for delivery. The interdisciplinary medical team must reach an agreement on the urgency of delivery, which

**Table 2.** Bio Physical Profile score

Variable	Score		
	2	1	0
Fetal breathing (FBM)	One episode lasting at least 60 sec within 30 min	One episode lasting 30- 60 sec within 30 min	No breathing movement or breathingmovements less than 30 sec within 30 min
Fetal reactivity (FR)	Definite reactivity (over 2acceleration in 30min)	Equivocal reactivity (1or 2 accelerations in 30 min)	No reactivity (no acceleration in 30 min)
Qualitative evaluation of amniotic fluid volume(AFV)	2 cm square or more	Between 1 cm and 2 cm	Less than 1 cm
Fetal tone	At least one episode involving both extremities and spine	At least one episode involving either extremities or spine	Extension movement of extremities not followed by return orflexion
Fetal Movement (FM)	3 or more in 30min	1 or 2 in 30 min	No movement in 30min



**Fig. 9.** Sample annotated image of a subject



**Table 3.** Interpretation of clinical results for subjects based on BPP score

Subject Id	Age	Weight (Kg)	Height (Cm)	Bio Physical Profile- parameters					Fetal Risk Condition
				Amniotic Fluid Level (AF)	Fetal Body Movement (FBM)	Fetal Breathing Movement (FBRM)	Placental Grading (PG)	Fetal Tone Movement (FT)	
001	35	68	156	2/2	2/2	2/2	2/2	2/2	Normal
002	28	69	166	2/2	2/2	2/2	2/2	2/2	Normal
003	35	76	163	2/2	2/2	2/2	2/2	2/2	Normal
004	26	82	158	0/2	0/2	0/2	0/2	0/2	Pathological
005	25	62	159	1/2	2/2	2/2	2/2	2/2	Normal
006	30	78	170	1/2	1/2	1/2	1/2	1/2	Suspicious
007	27	66	150	2/2	2/2	2/2	2/2	2/2	Normal
008	32	78	168	0/2	0/2	0/2	0/2	0/2	Pathological
009	22	65	169	2/2	2/2	2/2	2/2	2/2	Normal
010	25	53	158	1/2	1/2	0/2	1/2	1/2	Suspicious

must consider all factors such as gestational age, medical conditions, and hospital capabilities. BPP considers a variety of fetal well-being factors and is an effective tool for guiding management in high-risk obstetric cases. It is easily reproducible and can be performed in a wide range of settings, from the most remote to the most prestigious hospitals.

**Clinical Interpretation**

The aim of the proposed database was to inspire the research community to identify risk factors associated with pregnancy. The proposed database has been validated by radiologists and obstetricians using the BPP score. The pregnant women undergo an ultrasound test and the radiologist will generate an ultrasound video sequence. The videos are converted into frames once they are received. The images will be validated by the obstetrician using the BPP score. If any of the BPP parameters is found to be 0/2, the fetus’s condition is confirmed to be critical. Similarly, if any of the values is 1/2, the fetus’s condition is suspicious. If all of the values are 2/2, the condition is considered normal. To test the proposed database, the various subjects are evaluated by the obstetrician with a BPP score, and the condition of the fetus is also given in table 3.

Table 3 shows the clinical result of fetal ultrasound images for the 10 selected subjects and their respective risk status. The biophysical profile uses ultrasound and cardiotocography (CTG), also

known as electronic fetal heart rate monitoring, to examine the fetus. Five components are measured during the biophysical exam. Each component that meets the criteria in Table 3 receives a two-point score. The tests are repeated until either all criteria are met or 30 minutes have elapsed. The points are then added up for a total possible score of 2. The Normal amniotic fluid is defined as a total score of 2 points or 1 out of 2 points. A score of 0 indicates that there may be issues that need to be evaluated or monitored further. Based on Table 3, it is concluded that subjects 006 and 010 are suspicious, and subjects 004 and 008 are classified as having pathological conditions due to their low BPP score. The remaining subjects were discovered to be in Normal condition, with a good BPP score.

Figure 9 shows the sample annotated image of a subject. The obstetrician has evaluated subject 001, with the Biophysical profile score. In this all five BPP parameters show a 2/2 BPP score, so it’s confirmed that the fetus is in Normal condition only. Likewise, all the subjects will be evaluated by the obstetricians with the help of the Biophysical profile score. If the fetus is found to be in a pathological condition, immediate actions will be taken by the doctors. Through proper analysis of the ultrasound scan maternal abdominal images and their clinical results, we can prevent the fetus from risk conditions during the gestational period.

## CONCLUSION

The unusual changes in the heart rate of the baby in the uterus can be examined using CTG and BPP tests. In this paper, a new medical image database called BIOPHYSIT, which is a collection of ultrasound scan images has been for biomedical and healthcare application research. It is developed with the intention of providing a common benchmark for fetal stress condition research and related development. The main characteristics of this BIOPHYSIT database are: a) 300 ultrasound images have been collected from 50 female subjects b) explains the construction and composition of the database c) Annotation of the entire subject's biological data d) Clinical report with suggestions by the obstetrician for all the subjects. By providing this database available to the biomedical research community, we hope to promote the analysis of many uncertain problems. The BIOPHYSIT database along with all clinical measures will be publically made available for research.

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### Conflict of Interest

There are no conflict of interest.

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