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Evaluation of foetal mitral annular plane systolic excursion with conventional M-mode ultrasound in normal pregnancy

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Abstract
Background: Foetal mitral annular plane systolic excursion (fMAPSE) helps in the evaluation of the left foetal cardiac function, which is key in the early diagnosis of congenital heart defects and abnormalities.
Objectives: To assess foetal MAPSE in the second half of normal pregnancy, to establish reference ranges for this measurement in our environment, and to determine the relationship between foetal MAPSE and gestational age and estimated foetal weight.
Materials and Methods: This descriptive cross-sectional study was conducted between March 2022 and August 2022 at the Obstetric Units and Radiology Departments of the two tertiary facilities, one secondary facility and one radiodiagnostic facility in Bayelsa State, Nigeria. Consenting pregnant women presenting to the antenatal clinics of the study centres during the second half of pregnancy were consecutively included. Obstetric ultrasound scans were was transabdominally. Data were analysed using SPSS version 25.
Results: The correlation coefficient (ɼ) between fMAPSE and gestational age was 0.21 with a p-value of 0.001, reflecting a significant but weak relationship between fMAPSE and gestational age. There was a positively weak but significant relationship (ɼ = 0.29; p – 0.001) between fMAPSE and estimated foetal weight.
Conclusion: Our study revealed that there was a significant relationship between fMAPSE and gestational age, and between fMAPSE and estimated foetal weight, which correlates with published data around the globe.

Keywords: Foetal MAPSE, foetal cardiac function, gestational age, estimated foetal weight

Introduction

Global cardiac systolic function can be assessed by shortening fraction (SF) using two-dimensional (2D) ultrasound (US) or by ejection fraction (EF) using three-(3D) and four-(4D) dimensional US with spatio-temporal image correlation (STIC) and virtual organ computer-aided analysis (VOCAL) methods [1]. SF is assessed by measuring the reduction of the ventricular diameter of the end-diastole to end-systole [2]. EF reflects the percentage of blood ejected by the ventricles in each cardiac cycle, which can be used to evaluate the longitudinal myocardial function with good reproducibility [3].

Longitudinal/long-axis cardiac function is assessed by measuring the maximum mitral and tricuspid annular plane systolic excursions (MAPSE/TAPSE) by means of US using conventional anatomical M-mode tracings and by STIC M-mode (STIC-M) [1, 4]. MAPSE and TAPSE, by measuring the longitudinal contraction of the right heart, has been shown to be more reliable than the SF, which measures crosswise contraction of the ventricle [5]. Measurements of TAPSE, MAPSE, and septum annular plane systolic excursion (SAPSE), though provide mainly information on longitudinal/long-axis cardiac function, can also provide information on radial cardiac contractility. More so, whereas SF and EF are usually altered only in late stages of foetal cardiac dysfunction, TAPSE, MAPSE and SAPSE may be affected in the early stages of cardiac dysfunction, and can therefore aid early diagnosis of foetal cardiac dysfunction [4].

Ultrasound is currently widely used for assessment of foetal cardiac function. M-mode or “motion” mode is a time motion display of the US wave along a chosen US line. It allows motion-related changes in time along a single scan line to be displayed, acquired, and measured [6]. M-mode is the conventional imaging modality on most US machines and can be used to accurately measure changes in tissue excursion at precise points along a designated line of sight [7]. It has a high degree of accuracy and high time resolution, so that even very rapid movements of a structure can be recorded, displayed, and measured. M-mode US provides a monodimensional view of the heart and allows measurement of movement of the valve annulus as a surrogate for longitudinal ventricular function [8]. Several studies have demonstrated the effectiveness of M-mode US for assessing foetal cardiac function [9–12]. This study therefore sought to evaluate foetal mitral annular plane systolic excursion with convention M-mode US in normal pregnancy.

Materials and Methods

Study setting: This prospective, descriptive, cross-sectional study was conducted at the Obstetric Units and Radiology Departments of the Federal Medical Centre, Yenagoa, Niger Delta University Teaching Hospital, Okolobiri, Diete Koki Memorial Hospital, Yenagoa, and Silhouette Radiodiagnostic Consultants, Yenagoa, all in Bayelsa State, Nigeria. It was conducted from March 2022 – August 2022. The first two study centres are tertiary health facilities that provide specialised gynaecological services to women in Bayelsa State and serve as referral centres for other hospitals in Bayelsa State, and surrounding Rivers and Delta States, both in South-South Nigeria. The third study centre is a secondary health institution, while the fourth study centre is the biggest Radiodiagnostic Institution in Bayelsa State, Nigeria.

Sample size determination

The sample size for this study was calculated using the formula:

$n = z^2pq/d^2$ [13].

where:
n = minimum sample size
z = normal standard deviation set at 95% confidence limit = 1.96
p = proportion of women in the target population which is 50% (50% = 0.5) [13].
q = 1 – p (complementary probability).
d = margin of error = 5% = 0.05

Calculation
$n = (1.96)^2 \times 0.5 \times 0.5 / (0.05)^2$
n = 3.8416 x 0.5 x 0.5 / 0.0025
n = 0.9604 / 0.0025
n = 384.16
considering attrition = 10% of 384.16 = 38.41
therefore:
n = 384.16 + 38.41
n = 422.5
n was rounded off to 423.

Four hundred and twenty-three consecutive women were therefore recruited for this study. Consecutive patients that presented to the antenatal clinics of the study centres during the second half of pregnancy (20 – 40 weeks) were recruited for the study.

Inclusion criteria: Women with normal singleton, uncomplicated gestations, normal foetuses and no maternal medical conditions.

Exclusion criteria: Foetal aneuploidy, abnormal foetal growth, structural cardiac abnormalities, non-cardiac abnormalities, multiple gestation.

Women who met the inclusion criteria for the study were counselled, and after obtaining written informed consent, were enrolled. They were referred to the Radiology Departments of the study centres a routine obstetric ultrasound scan. The age, parity, gestational age, and any presenting complaints were obtained and documented. Gestational age was calculated from last normal menstrual period, which correlated with a first trimester ultrasound scan.

Procedure: Ultrasound scans were performed transabdominally, and were performed by Consultant Radiologists with special interests in foetal nephrology. The patient took about four glasses of water, to get the urinary bladder filled, about one hour before the procedure. A full bladder served as a good acoustic window. With the patient lying supine, and the abdomen and pelvis exposed, adequate ultrasound gel was applied to the lower anterior abdominal wall/pelvis. The gel served to remove air from the skin, and for ease of transducer movement.

A 2012 Philips HD11 machine, fitted with a 3.5 MHz curvilinear (convex) transducer (probe) was used. It was moved back and forth on the skin, and in orthogonal planes, with gain adjusted, as required, for good image quality. Foetal biometry and estimated foetal weight were calculated using the Hadlock method [14]. Foetal MAPSE was measured in the 4-chamber view, with the cardiac apex at 12- or 6-o’clock. The conventional M-mode imaging was used, where the M-mode beam was aligned through the lateral aspect of the mitral valve annulus, parallel to the interventricular septum at ±15°. This is most appropriate for the measurement of the maximum movement of the annulus. The vertical movement (excursion), of the tricuspid annulus, measured in millimeters during systole and diastole was obtained from the amplitude of the M-mode wave. Optimization of the 4-chamber view was performed, and measurements recorded. These recordings were obtained at a place where maternal breath was held, and in the absence of foetal breathing movements in other to reduce non-cardiac movements. At least three measurements of foetal MAPSE were obtained and the mean taken. For the calculation of interobserver and intraobserver variation, foetal MAPSE was measured in 50 patients by two Consultant Radiologists. This process minimized interobserver and intraobserver errors.

Data Analysis: Statistical Product and Service Solutions for Windows® version 25, (SPSS Inc., Chicago, USA), was used to enter and analyze the data after they had been collected using a proforma that had been pre-designed. After a normality (Shapiro-Wilk) test confirmed that the variables were normally distributed, the results were shown as frequencies and percentages for categorical variables and the mean and standard deviation for continuous variables. The

Pearson's correlation analysis was used to assess the relationship between the fMAPSE, gestational age, and estimated foetal weight. After that, the correlation between fMAPSE and estimated foetal weight and fMAPSE and gestational age was determined using logistic regression analysis. A nomogram was created using the equation (equation is not stated). The intraclass correlation coefficient (ICC) was employed to calculate the inter- and intra-observer variations. The $p<0.05$ at 95% confidence interval level of significance was set.

Ethics: Ethical approval for this study was obtained from the Research and Ethics Committee of the Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria (FMCY/REC/ECC/2022/627).

Results

Maternal characteristics

There were 423 pregnant women recruited for this study. Majority of women were aged between 25 – 29 years (31.6%). Women aged 30 – 34 years and those aged ≥ 35 years were 23.6% and 22.0% respectively (Table 1). The mean age was 29.0 ± 6.3 years. About 2 in every 5 women recruited for the study were overweight (39.5%) and nulliparous (41.8%). One hundred and twenty-one women (28.6%) were in the second trimester while 302 women (71.4%) were in their third trimester of pregnancy.

Mean fMAPSE at specific gestational age and estimated foetal weight

Mean fMAPSE ranged from 3.05 ± 0.66 mm at 20 weeks' gestation to 7.70 ± 0.67 mm at 40 weeks' gestation. Foetuses with estimated weight of 500 grams had a mean fMAPSE of 2.30 ± 0.46 mm, which increased gradually to 7.00 ± 0.98 mm, 8.10 ± 0.46 mm and 8.70 ± 0.98 mm among foetuses weighing 3,300 grams, 3,800 grams and 4,000 grams respectively. Table 2 presents the mean fMAPSE and standard deviation at specific gestational age and estimated foetal weight.

Relationship between gestational age and fMAPSE

The correlation coefficient (ɼ) between fMAPSE and gestational age was 0.21 with a p-value of 0.001 reflecting a significant but weak relationship between fMAPSE and gestational age (Table 3). The ɼ^{2} of 0.05 showed that a unit change in gestational age was responsible for a 5% change in fMAPSE among this study population. The relationship between fMAPSE and gestational age (Figure 2) in this study was further defined by a regression equation shown in Equation 1: *fMAPSE = 0.335 + 0.006 x Gestational age.*

Relationship between estimated foetal weight and fMAPSE

There was a positively weak but significant relationship (ɼ = 0.29; p – 0.001) between fMAPSE and estimated foetal weight (Table 3). Equation 2 shows the regression coefficients between fMAPSE and estimated foetal weight (Figure 3). Tables 4 and 5 present the reference values for fMAPSE calculated from the regression equations for gestational age and estimated foetal weight respectively. Equation 2: fMAPSE = 0.441 + 0.041 x Estimated foetal weight. Table 6 revealed the inter- and intra-observer variations that were evaluated with the intraclass correlation coefficient (ICC).

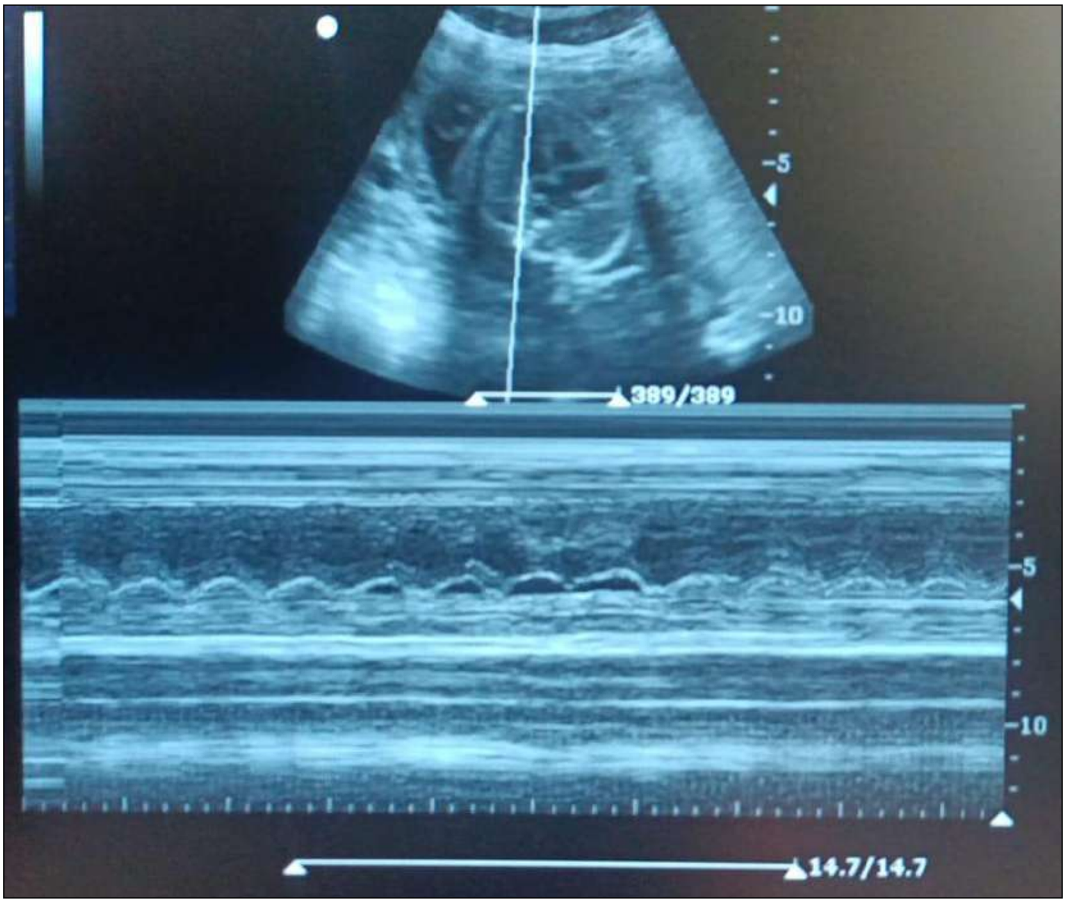

Fig 1: Sonogram showing foetal mitral annular plane systolic excursion (fMAPSE)

Table 1: Maternal Characteristics

Characteristics	Frequency N = 423	Percent (%)
Age (years)		
<20	34	8.0
20 – 24	65	15.4
25 – 29	131	31.0
30 – 34	100	23.6
>35	93	22.0
Body mass index		
Normal weight	119	28.1
Overweight	167	39.5
Obesity	137	32.4
Parity		
Nulliparity	177	41.8
Primiparity	70	16.5
Multiparity	139	32.9
Grand-multiparity	37	8.7
Gestational age (weeks)		
20 – 24	70	16.5
25 – 28	51	12.1
29 – 32	74	17.5
33 – 36	165	39.0
37 – 40	63	14.9

Table 2: Mean fMAPSE at specific gestational age and estimated foetal weight in the second half of pregnancy.

Gestational age in weeks	Frequency	Mean fMAPSE ± SD in mm	Estimated foetal weight in grams	Frequency	Mean fMAPSE ± SD in mm
20	6	3.05 ± 0.66	500	6	2.30 ± 0.46
21	12	3.37 ± 0.19	540	12	2.70 ± 0.23
22	13	3.47 ± 0.82	590	13	3.10 ± 0.38
23	13	3.50 ± 0.53	610	13	3.50 ± 0.78
24	26	4.00 ± 0.26	680	13	3.80 ± 0.82
25	13	4.60 ± 0.34	740	13	4.00 ± 0.67
26	13	4.90 ± 0.71	970	26	4.20 ± 0.65
27	6	4.95 ± 0.97	980	6	4.60 ± 0.78
28	19	5.10 ± 0.99	1100	6	4.60 ± 0.84
29	12	5.27 ± 0.71	1200	25	4.98 ± 0.67
30	13	5.35 ± 0.74	1600	13	5.00 ± 0.53
31	25	5.47 ± 0.54	1700	25	5.10 ± 0.65
32	24	5.60 ± 0.92	1800	12	5.60 ± 0.96
33	26	5.70 ± 0.87	2000	13	5.30 ± 0.65
34	25	5.60 ± 0.43	2100	14	5.40 ± 0.21
35	37	5.75 ± 0.35	2200	14	5.62 ± 0.47
36	77	6.01 ± 0.84	2400	13	5.60 ± 0.65
37	13	6.09 ± 0.16	2500	13	5.70 ± 0.43
38	12	6.50 ± 0.48	2700	14	5.90 ± 0.87
39	13	7.11 ± 0.85	2800	39	6.02 ± 1.09
40	25	7.70 ± 0.67	2900	27	6.50 ± 1.24
			3000	26	6.05 ± 0.05
			3300	14	7.00 ± 0.98
			3600	13	7.70 ± 1.03
			3800	27	8.10 ± 0.46
			4000	13	8.70 ± 0.98

Table 3: Relationship between gestational age, estimated foetal weight and fMAPSE.

Characteristics	Gestational age	Estimated foetal weight
Correlation indices		
Correlation coefficient (r)	0.21	0.29
r^2	0.05	0.08
p-value	0.001	0.001
Regression coefficient		
Constant (β_0)	0.335 (0.248 – 0.422)	0.441 (0.408 – 0.473)
Coefficients (β_1)	0.006 (0.003 – 0.009)	0.041 (0.028 – 0.055)

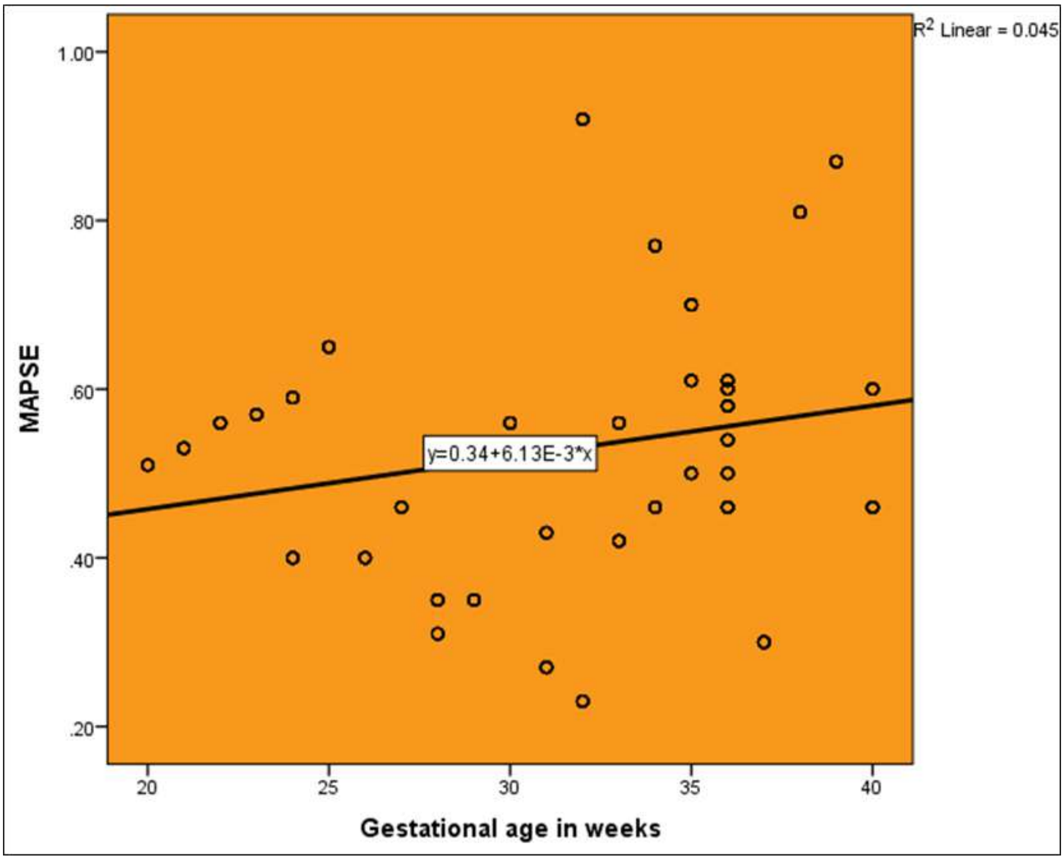

Fig 2: Line graph showing the relationship between fMAPSE and gestational age

Table 4: Nomogram showing reference ranges for fMAPSE at the different gestational age

Gestational age in weeks	Estimated fMAPSE	95% CI for Estimated fMAPSE	
		Min	Max
20	4.55	3.08	6.02
21	4.61	3.11	6.11
22	4.67	3.14	6.20
23	4.73	3.17	6.29
24	4.79	3.20	6.38
25	4.85	3.23	6.47
26	4.91	3.26	6.56
27	4.97	3.29	6.65
28	5.03	3.32	6.74
29	5.09	3.35	6.83
30	5.15	3.38	6.92
31	5.21	3.41	7.01
32	5.27	3.44	7.10
33	5.33	3.47	7.19
34	5.39	3.50	7.28
35	5.45	3.53	7.37
36	5.51	3.56	7.46
37	5.57	3.59	7.55
38	5.63	3.62	7.64
39	5.69	3.65	7.73
40	5.75	3.68	7.82

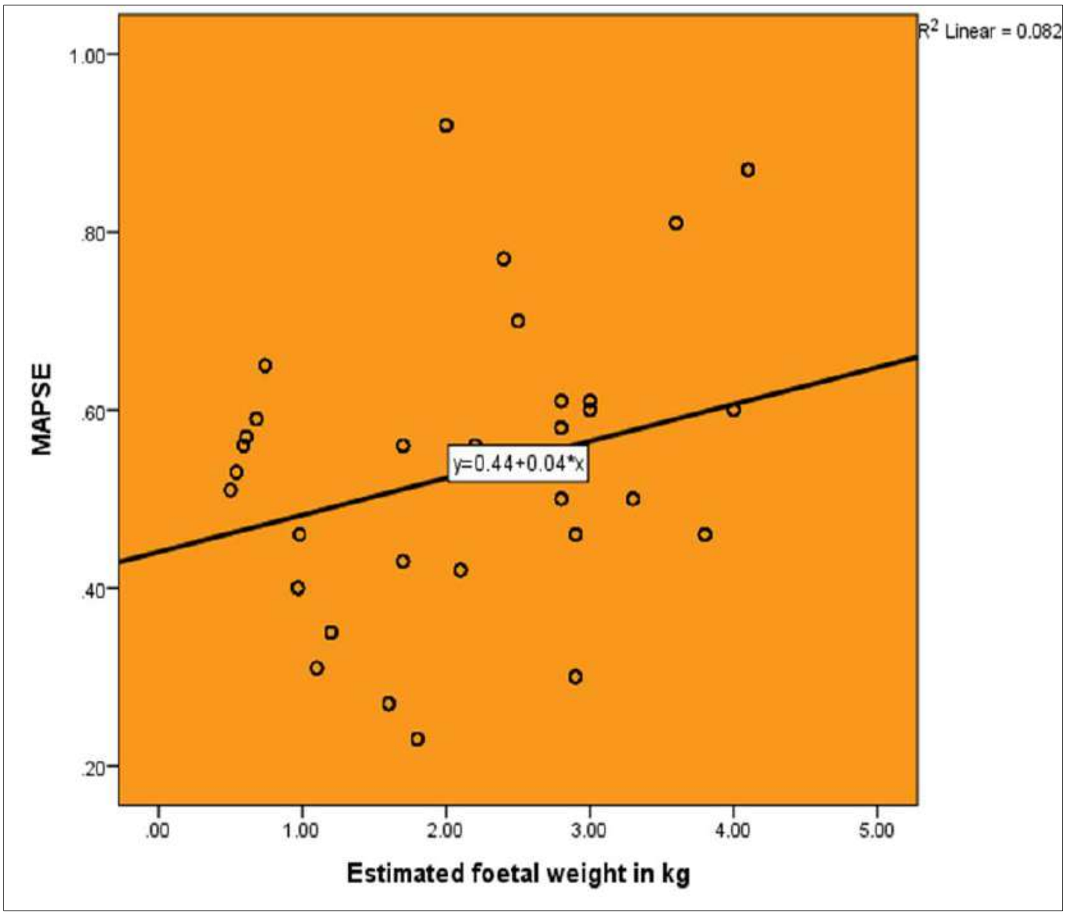

Fig 3: Relationship between fMAPSE and estimated foetal weight

Table 5: Nomogram showing reference ranges for fMAPSE at estimated foetal weight

Estimated foetal weight in grams	Estimated fMAPSE	95% CI for Estimated fMAPSE	
		Min	Max
400	4.57	4.19	4.95
500	4.62	4.22	5.01
600	4.66	4.25	5.06
700	4.70	4.28	5.12
800	4.74	4.30	5.17
900	4.78	4.33	5.23
1000	4.82	4.36	5.28
1100	4.86	4.39	5.34
1200	4.90	4.42	5.39
1300	4.94	4.44	5.45
1400	4.98	4.47	5.50
1500	5.03	4.50	5.56
1600	5.07	4.53	5.61
1700	5.11	4.56	5.67
1800	5.15	4.58	5.72
1900	5.19	4.61	5.78
2000	5.23	4.64	5.83
2100	5.27	4.67	5.89
2200	5.31	4.70	5.94
2300	5.35	4.72	6.00
2400	5.39	4.75	6.05
2500	5.44	4.78	6.11
2600	5.48	4.81	6.16
2700	5.52	4.84	6.22
2800	5.56	4.86	6.27
2900	5.60	4.89	6.33
3000	5.64	4.92	6.38
3100	5.68	4.95	6.44
3200	5.72	4.98	6.49
3300	5.76	5.00	6.55

3400	5.80	5.03	6.60
3500	5.85	5.06	6.66
3600	5.89	5.09	6.71
3700	5.93	5.12	6.77
3800	5.97	5.14	6.82
3900	6.01	5.17	6.88
4000	6.05	5.20	6.93

Table 6: Interobserver and intraobserver intraclass correlation coefficient results

Ultrasound parameter	Intraclass correlation coefficient	
	Interobserver	Interobserver
fMAPSE	0.98 (95% CI 0.39 – 0.99)	0.98 (95% CI 0.41 – 0.99)

Discussion

With a conventional 2D ultrasound and the anatomical M-mode, which is easily accessible in resource-poor settings, measurements of the foetal mitral annular plane systolic excursion (fMAPSE) can be easily taken. For evaluating the longitudinal systolic cardiac function of foetuses, it is a straightforward and frequently helpful approach. This study aimed to evaluate fMAPSE in the second half of normal pregnancy, define reference ranges for fMAPSE measurement in our setting, and explore the association between fMAPSE and estimated foetal weight and gestational age.

Our study revealed that fMAPSE measurement values increased linearly during pregnancy and that there was a positive association between estimated foetal weight and gestational age.

Using both anatomic and conventional M-mode, increase in fMAPSE throughout the course of gestation has previously been reported from researches conducted in other parts of the world, and our findings are in tandem with these reports [4,8,9,11,15,16]. This radiological feature of the foetal left ventricular function in normal pregnancy has not yet been extensively investigated, especially in Nigeria. The majority of the reported investigations had focused on evaluating right and left ventricular performance in adults with heart conditions [17–21]. A few other authors compared cardiac function between foetuses of women with diabetes mellitus in pregnancy and those with normal pregnancies [1, 8].

According to our research, fMAPSE values rise linearly with both gestational age and foetal weight. Therefore, it was considered more helpful to have a reference range for fMAPSE for age and weight (as documented in our results) rather than a single value, taking into account continuous developmental changes. The linear increase is shown to be within a 95% confidence interval, indicating the minimum and maximum ranges for each gestational age and weight. This has clinical significance as it shows that the linear increase is within that interval.

Our study produced a nomogram for fMAPSE values which ought to give reliable normal values across the preterm and term neonatal spectrum, especially for our region. Therefore, our findings have made great efforts to establish normal reference values for fMAPSE for gestational age and weight in foetuses from the second trimester to term and could serve as reference ranges for foetuses with sonographically normal hearts and possibly congenital heart defects to help detect those with impaired left ventricular systolic function. Uncertainty however exists regarding the significance of results below the minimal reference ranges in otherwise healthy foetuses.

The ICC was used in our study to reduce inter- and intra-observer variability for the measurements of fMAPSE. The inter- and intra-observer variance values in this study were 0.98 each, indicating an almost perfect agreement. A value greater than 0.8 indicates an almost perfect agreement, and the normal range is 0 – 1.[22]

This research has revealed that the 2D M-mode ultrasonographic technique is safe, practical, and non-invasive. This study is constrained, nevertheless, in that we cannot completely rule out bias in the agreement between the measured MAPSE and computed MAPSE for both the estimated gestational age and the estimated foetal weights. Furthermore, this was a cross-sectional, rather than a longitudinal study.

Conclusion

Our study revealed that fMAPSE measurement values increased during the course of pregnancy, and that there was a significant relationship between fMAPSE and gestational age; and between fMAPSE and estimated foetal weight, which correlate with published data around the globe. We strongly recommend more robust studies (especially longitudinal) to be carried out in Nigeria, as there are few or no studies on this subject matter in our region.

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The research was funded by the authors.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

EKK conceptualised the study, carried out obstetric ultrasound scans and collected data. PCO designed the study, collated data, wrote the methodology and discussion. AEU wrote the introduction. DCB contributed to writing the discussion. JUU did obstetric ultrasound scans. PYB, AOA and IJA recruited patients from the obstetrics units. CO wrote the abstract. ADA analysed data and wrote the results. All the authors read and approved the final manuscript**.**

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