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### EVALUATION OF UMBILICAL ARTERY DOPPLER INDICES IN NORMAL PREGNANCIES IN A NIGERIAN POPULATION

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#### ABSTRACT

**Background:** Umbilical artery (UbA) Doppler sonography is a potential screening tool for pregnancy complications in placenta insufficiency. Assessment of the maternal and fetal vessels in pregnancy ensures accurate identification and prediction of pregnancy complications, such as preeclampsia (PE) and intrauterine growth restrictions (IUGR). The study aims to establish local reference values for UbA in a Nigerian population. **Methods:** A prospective longitudinal study was conducted among 230 pregnant women between April 2021 and March 2022. All participants had their fetal umbilical artery UbA evaluated with a Doppler ultrasound from 11 to 30 weeks 6 days of gestational age. Peak systolic velocity (PSV), End diastolic Velocity (EDV), Systolic/Diastolic ratio (S/D), Pulsatility Index (PI), and Resistivity Index (RI) were measured and documented.

**Results:** The mean umbilical artery (UbA) Doppler indices at 11 weeks 0 day - 30 weeks 6 days GA ranged as follows 0.87 - 0.65 (RI), 2.53 - 1.05(PI), 16.42 - 2.84 (S/D ratio), 41.37 - 64.86 cm/s (PSV) & 16.27 - 20.93 cm/s (EDV) respectively.

**Conclusion:** The umbilical artery Doppler reference range was established in the study population. These reference ranges will be of clinical value in daily obstetric and sonography practice. It is our opinion that data from this study will be beneficial to obstetricians, sonographers, and researchers in the evaluation of the umbilical arteries and the possible prediction and management of pregnancies in a similar population.

**Keywords:** Doppler indices, umbilical artery, Pre-eclampsia, Intrauterine growth restriction.

## Introduction

Ultrasound examination has become an integral part of antenatal care all over the world. However, the benefit of obstetric ultrasound is yet to be fully realized in sub-Saharan Africa, hence the greatest burden of poor perinatal outcomes (1). Most women in sub-Saharan Africa still go through pregnancy without the benefit of ultrasound examination (1, 2, 3). Sub-Saharan Africa has been reported to be responsible for the majority of the global burden of perinatal morbidity and mortality (4, 5, 6). Globally, the benefit of antenatal ultrasound care is well established, but efforts are needed towards making umbilical artery (UbA) Doppler ultrasound a compulsory part of comprehensive antenatal care in developing countries (1). There is no precise guidance on its appropriate use in antenatal care in developing countries, especially in sub-Saharan Africa (1, 7, 8, 9, 10). This imaging modality provides a non-invasive method of assessing the physiological functions of the placenta and fetal circulation. Increased resistance to blood flow is an indication of an increased risk of pregnancy complications and an indication of a possible need for intervention. It is widely used in high-risk pregnancies to identify fetal compromise and to predict pregnancy complications, particularly intrauterine fetal growth restriction (IFGR) and pre-eclampsia (PE) in apparently healthy pregnancies to reduce perinatal mortality (11, 12, 13). Pre-eclampsia (PE) is an important public health challenge in both developed and developing countries with high maternal and perinatal morbidity and mortality (14, 15, 16). Doppler assessment of UbA is often indicated in suspected cases of pregnancy complications or poor perinatal outcomes such as IUGR, decrease in fetal movement, oligohydramnios, polyhydramnios, maternal renal diseases, diabetes mellitus, and chronic renal disease (20). Doppler Ultrasound waveforms not only reflect blood velocity but also provide information on various aspects of blood flow like presence and direction of flow, velocity profile, flow volume, and impedance. The fetal umbilical artery Doppler is a non-invasive method of assessing impedance within the fetoplacenta circulation and is an indirect measure of resistance to flow within the placenta vasculature in

pregnancy (27). Umbilical artery Doppler assessment provides useful information about underlying increases in placenta vascular resistance which are measured using the following Doppler equations: Resistivity index (RI):  $\frac{\text{Peak systolic velocity} - \text{diastolic velocity}}{\text{peak systolic velocity}}$ , Systolic/Diastolic Ratio (S/D):  $\frac{\text{Peak systolic velocity}}{\text{diastolic velocity}}$ , and pulsatility index (PI):  $\frac{\text{Peak systolic velocity} - \text{diastolic velocity}}{\text{mean velocity}}$  respectively. Any of the above equations can be used to assess the hemodynamic changes in the umbilical artery in pregnancy. As a normal pregnancy progresses from the first trimester to the second and third trimester, the resistance in the placenta and the umbilical arteries decrease. It is abnormal for the placenta and the umbilical artery resistance to continue to increase, reducing or absent end-diastolic flow, and consequently increase in either PI or RI. The umbilical artery blood flow is influenced by the rapid rate of the normal fetal heart rate beats per minute which leads to a constant forward flow of blood toward the placenta, during both diastole and systole cycles of the heart. Usually, a normal umbilical artery Doppler waveform has a low resistance pattern throughout the gestational period. It is an objective assessment of the Doppler waveform which serves as a surrogate maker for the well-being of the fetus in utero through the assessment of impedance within the fetoplacenta circulation and it is an indirect measure of resistance to flow within the placenta vasculature (28) Abnormal umbilical, artery Doppler is a marker of placenta insufficiency and consequent IUGR or suspected PE.

Doppler indices commonly measured are peak systolic velocity, PSV), end-diastolic velocity (EDV), time average velocity (TAV), systolic/diastolic ratio (S/D ratio), resistivity index (RI), and pulsatility index (PI) (22). In IUGR fetuses and fetuses developing intrauterine distress, the umbilical artery blood velocity waveform usually changes in a progressive manner such that there will be a reduction in end-diastolic flow, increasing RI, PI, and S/D ratio values, or absent EDV flow, or reversal EDV flow (21). Umbilical vein flow is usually a monophasic, non-pulsatile flow pattern, with a mean velocity of 10-15 cm/s. Since a normal

umbilical vein supplies a continuous forward flow of oxygenated blood to the fetal heart, the presence of pulsatility implies a pathological condition unless in a certain condition such as fetal hiccups, fetal breathing movement, or early in pregnancy up to 13 weeks of gestation (17). Pulsations of the umbilical venous system, especially double pulsations, have been associated with an increase in perinatal mortality when associated with the absent and reversed end-diastolic flow velocity in the umbilical artery (17). Therefore, this research work aims to evaluate fetal UbA. in order to establish a reference range for normal pregnancies in a Nigerian population using Doppler ultrasound to improve the management of pregnancy in our locality. The purpose of this study was to evaluate UbA with Doppler Ultrasound from 11 – 30 weeks 6 days of gestation in normal pregnancies in a Nigerian population and establish Local Reference Values for fetal umbilical artery in normal pregnancies. There is currently a paucity of literature on fetal umbilical artery indices and their application in the prediction of women at risk of developing pregnancy complications in the study population. The need for the local Population Reference Values (LPRV) was necessitated by documented evidence showing anthropometric and genetic variations based on ethnic/racial differences (29,30, 31). Currently, the parameters in use are generated or developed for the developed countries, Nigeria being a developing country is ethnically different from the Western countries i.e. the two populations are ethnically different. Hence the need to develop the reference range for our local population.

### Methods:

This study adopted a prospective longitudinal method to evaluate the umbilical arteries of 230 healthy subjects using Doppler ultrasound at Esteem Diagnostic Medical Services Limited (EDMSL) and Onikan General Hospital, Lagos State (OGHLS), Nigeria between March 2021 and April 2022. Doppler waveforms of the UbA were observed, analyzed, and measured. The following Doppler indices were recorded; PSV, EDV, S/D ratio, PI, and RI by an experienced, certified, and licensed sonographer. An

initial obstetric ultrasound examination was carried out for inclusion criteria, fetal age determination, and documentation of Doppler indices. Participants were recruited by Obstetricians/Gynecologists and trained nurses. Thereafter, the participants were evaluated for inclusion and exclusion criteria. All participants that met the inclusion criteria and consented to participate in the study were enlisted. The inclusion criteria were active and live singleton pregnancy, absence of a history of a medical disorder in pregnancy, absence of open wound within the suprapubic and umbilical region, ability to stand erect for weight and height measurements, and gestational age (GA) between 10 weeks and 11 weeks based on the last menstrual period and from a baseline ultrasound scan. The participants were given consent forms to complete and sign after a thorough explanation of the aim, objectives, and procedures of the study in the language they understand. The anthropometric parameters were obtained using a weighing scale with a stadiometer, and the blood pressure with an automated sphygmomanometer. The participants completed the questionnaires before the first baseline ultrasound examination was conducted. Ethical approvals were obtained from the University of Health and Allied Sciences Research Educational Committee (UHAS-REC), the Nigerian Institute of Medical Research – Institutional Research Review Board (NIMR-IRB), and the Lagos State Health Services Commission (LSHSC). Moreover, permission to enroll the participants and use the facilities was obtained from the management of EDMSL and OGHLS, respectively. MySono U6 ultrasound equipment (Samsung manufactured in Korea in February 2013) was used for the study. Twenty-eight participants were lost to follow-up (attrition). A total of 230 volunteers were recruited, but 202 participants were able to complete the five (5) serial scan while the remaining 28 participant were loss to attrition. Each participant had five consecutive serial scan and measurements at the following periods: 11- 14 weeks, 15 - 18 weeks, 19 - 22 weeks 23-26weeks, and 27 - 30 weeks, respectively. All the 202 participants had the umbilical artery of their fetuses evaluated and their blood pressure measured at

every visit. Participants were asked to lie supine on a couch in a semi-recumbent position with a slight lateral tilt in such a way that allows easy blood circulation in the body and guards against compression of the abdominal aorta and inferior vena cava (IVC) which could cause hypotension. This study adopted the transabdominal route for the convenience and privacy of the participants. The umbilical artery Doppler examination, waveform generation, analysis, measurement, and documentation were carried out at the free loop of the cord in the absence of fetal movement or maternal movement, or uterine contraction, for simplicity, consistency, and accuracy. The Doppler sample gate was set to 2 mm to cover the whole vessel and reduce aliasing. The wall filter was set at 50-60 Hz, and the angle of insonation was kept at 30° ( $\leq 30^\circ$ ). After 3 consecutive Doppler waveforms, images were frozen, analyzed, measured, and documented for the umbilical artery. Data were analyzed using the statistical package for the social sciences (SPSS) version 25.

### Results:

The mean age of the respondents was 29 years (range 17 to 46 years). The mean height was 1.63 m (range 1.19 to 1.95). The mean BMI was 26.68 kg/m<sup>2</sup>, (range 13.21 to 48.84). A total of 96.5 % of the respondents were educated but only 1 % of the study population have previous knowledge of Doppler ultrasound. Only 5 % of the respondents had a previous history of. Few of the respondents, 13.4 % and 3 % had a previous history of cigarette smoking and alcoholic consumption, respectively. The majority (79.8 %) of the respondents were married, 16.8 % were single, and 0.5 % were separated. Less than half of the respondents (49.5 %) were multiparous while the rest were nulliparous (Table 1).

Table 1: Demographic characteristics of the study population

	Mean (SD)	Minimum	Maximum
Age (years)	29 (5.9)	17	46
Height (m)	1.63 (0.1)	1.19	1.95
Weight (Kg)	69.67 (15.4)	40	125

The mean range of umbilical artery Doppler indices from 11 weeks 0 day – 30 weeks 6 days GA were PSV= 41.37 m/s – 64.86 cm/s, EDV = 16.27 cm/s – 20.93 m/s, S/D ratio =16.42 – 2.84, RI = 0.87 - 0.65, PI = 2.53 – 1.05 respectively. There was an observed increase in the values of PSV and EDV as the GA increases (pregnancy advances) with a corresponding decrease in the values of S/D, RI, and PI. However, there was a moderate decrease in EDV from 11wk 0d – 14wks 6day from 16.27 cm/s  $\pm$  29.15 to 8.92 cm/s  $\pm$  14.03 at 15wks 0d to 18wks 6d of GA and with a sudden increase from 9.52 cm/s  $\pm$  12.06 - 20.93 cm/s  $\pm$  14.01 from 19wks 0d to 30 wks. 6d of GA (see Table 2).

The male and female UbA Doppler indices were evaluated and compared (Table 3). There was an observed marginally higher value of EDV, RI, and PI with a resultant lower value of PSV and S/D ratio noted in the female fetuses compared to the male fetuses. Although no significant statistical differences were observed ( $p > 0.05$ ). However, the S/D ratio, RI, and PI values decrease with an increase in fetal gestational age in both genders. All fetuses in the study population had two umbilical arteries.

The placenta position was evaluated with fetal gender determination, it was noted that there was no statistical relationship between placenta location and gender determination ( $P = 0.111$ ).

This study also evaluated and compared the mean values of male and female fetuses heart rates measured in beats per minute (b/m) from 11 weeks 0 days – 30 weeks 6 days of GA as follows; 153.84 - 133.49 b/m, 129 - 125.00 b/m (minimum) and 177.00 b/m - 160.00 b/m (maximum). There was a minimal increase in female fetuses' heart rate compared to male fetuses. (Table 5 & 6).

<b>BMI (Kg/m<sup>2</sup>)</b>		26.68 (6.1)	13.21	48.82		
<b>Blood pressure</b>	1 <sup>st</sup> visit mm/Hg	107/73 (14/7)	70/59	133/93		
	2 <sup>nd</sup> visit mm/Hg	103/73 (14/8)	72/59	113/93		
	3 <sup>rd</sup> visit mm/Hg	106/75 (13/8)	77/59	130/93		
	4 <sup>th</sup> visit mm/Hg	106/75 (12/8)	79/59	130/93		
	5 <sup>th</sup> visit mm/Hg	108/76 (12/7)	80/60	124/92		
<b>Parity</b>	<b>Nulliparous- Freq (%)</b>			<b>Multiparous- Freq(%)</b>		
	103 (50.5)			99 (49.5)		
<b>Gravidity (G)</b>	<b>G1 (%)</b>	<b>G2 (%)</b>	<b>G3 (%)</b>	<b>G4 (%)</b>	<b>G5 (%)</b>	<b>≥G6 (%)</b>
	50 (24.8)	73 (36.4)	34 (16.8)	27 (13.4)	11 (5.4)	6 (3.0)
				<b>Yes. (%)</b>	<b>No (%)</b>	
<b>Knowledge of Doppler ultrasound in pregnancy</b>				2 (1.0)	193 (99.0)	
<b>Any history of pre-eclampsia</b>				10 (5.0)	192 (95.0)	
<b>Prevalence of smoking among the study population</b>				6 (3.0)	189 (93.6)	
<b>Prevalence of alcoholism among the study population</b>				27 (13.4)	167 (82.7)	
<b>Marital status</b>	<b>Married Freq. (%)</b>			<b>Single. (%)</b>	<b>Divorced(%)</b>	
	160 (79.8)			34 (16.8)	1 (0.5)	
<b>Education Qualification</b>	<b>Nil (%)</b>	<b>Informal (%)</b>	<b>Primary (%)</b>	<b>Secondary(%)</b>	<b>Tertiary (%)</b>	
	7 (3.5)	2 (1.0)	21 (10.4)	90 (44.6)	75 (37.1)	

Table 2: Umbilical artery Doppler indices

	<b>11 – 14 wks</b>		<b>15 – 18 wks</b>		<b>19 – 22 wks</b>		<b>23 - 26</b>		<b>27 – 30 wks</b>	
<b>PSV (cm/s)</b>	41.37	28.08	40.38	19.74	43.31	20.70	47.56	18.45	64.86	29.62
<b>EDV (cm/s)</b>	16.27	29.15	8.92	14.03	9.52	12.06	17.51	16.46	20.93	14.01
<b>S/D</b>	16.42	15.45	10.46	11.04	9.26	8.88	4.20	3.01	2.84	0.92
<b>RI</b>	0.87	0.28	0.84	0.14	0.83	0.12	0.74	0.16	0.65	0.12
<b>PI</b>	2.53	1.18	1.95	0.84	1.86	0.64	1.37	0.53	1.05	0.34

Table 3: Male and female umbilical Doppler indices

Umbilical artery doppler indices	11 – 14 WKS (SD)	15 – 18 wks (SD)	19 – 22 wks	23 – 26 wks (SD)	27 – 30 WKS (SD)	
<b>Male</b>	<b>PSV (cm/s)</b>	44.04 (33.3)	41.08 (22.0)	44.16 (20.7)	47.38 (18.4)	65.53 (31.6)

	<b>EDV</b>	18.77 (32.8)	9.92 (17.9)	9.92 (11.4)	17.99 (16.6)	19.12 (11.3)
	<b>(cm/s)</b>					
	<b>S/D</b>	16.94 (17.0)	11.48 (11.7)	8.34 (8.5)	3.60 (1.9)	2.85 (1.1)
	<b>RI</b>	0.85 (0.3)	0.84 (0.2)	0.81 (0.1)	0.71 (0.20)	0.65 (0.1)
	<b>PI</b>	2.52 (1.1)	2.04 (1.0)	1.82 (0.6)	1.33 (0.5)	1.07 (0.3)
	<b>PSV</b>	39.28 (22.9)	39.83 (17.9)	42.64 (20.7)	47.71 (18.7)	64.34 (28.1)
	<b>(cm/s)</b>					
<b>Female</b>	<b>EDV</b>	14.30 (25.9)	8.13 (10.1)	9.21 (12.6)	17.13 (16.4)	22.35 (15.7)
	<b>(cm/s)</b>					
	<b>S/D</b>	16.00 (14.2)	9.65 (10.2)	9.98 (9.1)	4.67 (3.6)	2.83 (0.8)
	<b>RI</b>	0.89 (0.3)	0.84 (0.1)	0.85 (0.1)	0.76 (0.1)	0.66 (0.1)
	<b>PI</b>	2.53 (1.2)	1.89 (0.7)	1.90 (0.6)	1.41 (0.6)	1.04 (0.3)

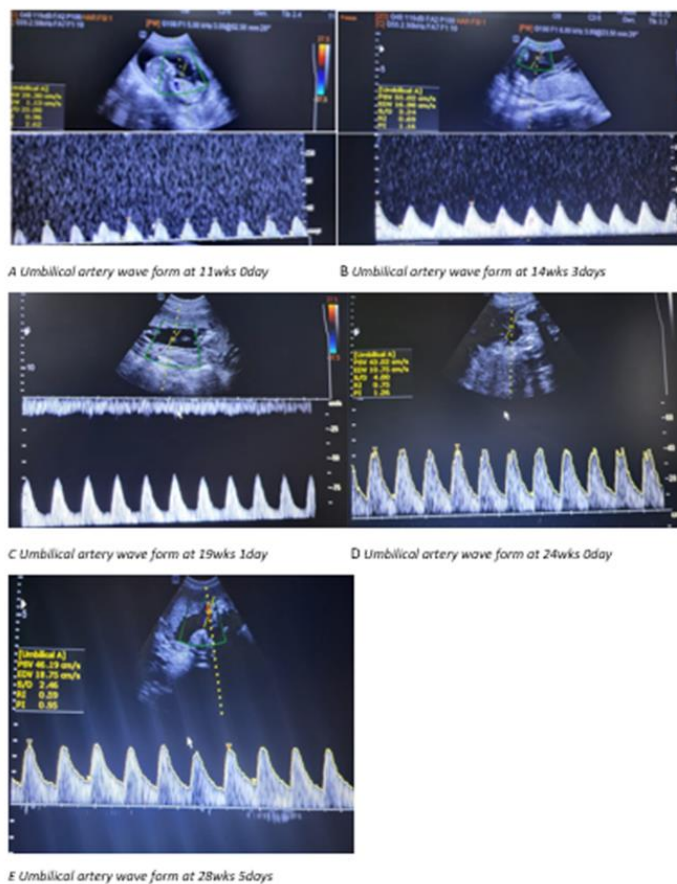


Figure 1: Umbilical artery doppler indices between 11 and 28 weeks

The representative ultrasound images of the umbilical artery from 11 weeks 0 days to 28 weeks 5 days. A. representing 11 weeks 0 days, B. 14 weeks 3 days, C.

19 weeks 1 day, D. 24 weeks 0 days, and E. 28 weeks 5 days respectively. At the late first trimester and early second trimester of the pregnancy, the umbilical artery demonstrates a minimal end-diastolic flow due to higher peripheral resistance in the placenta because the placenta is composed of fewer vessels at this age, but placenta vessels continue to increase as the pregnancy progresses into the third trimester. Thus, the end-diastolic forward flow continues to increase as the placenta vessel increases.

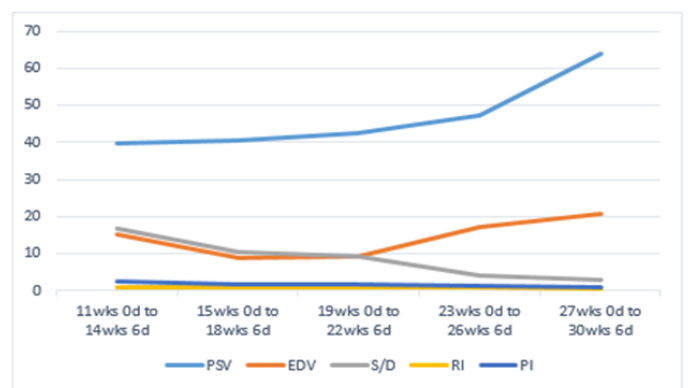


Figure 2: Umbilical artery doppler trend between 11 and 28 weeks

**Discussion:**

Doppler assessment of fetal umbilical artery in pregnancy provides a safe and non-traumatic method of evaluation of fetal and placenta blood circulation wave patterns and vascularity of placenta. The use of Doppler

ultrasound in the detection of normal, abnormal Doppler wave pattern, prediction of pregnancy complications and adverse pregnancy outcome was suggested by various studies (Inhibin & activin. 2011, Papageorghiou, Yu, Nicolaides 2004). Primarily, Doppler velocimetry in fetal medicine evaluates fetal hemodynamics which is capable of detecting changes due to placenta perfusion in pregnancy.

This study adopted a transabdominal route for patients' privacy, as most participants objected to the transvaginal route and refused to participate or take part in the study. This necessitated using the transabdominal route. The measurement and analysis of UbA waveforms were taken at the free loop of the UbA for easy generation of waveforms and consistency in measurement. This method was adopted by Kennedy and Woodward (20), They reported significant differences in the Doppler spectral indices measured at the fetal end, the free loop, and the placental end of the umbilical cord. They stated that impedance is highest at the fetal end due to fetal tone and body movement, and relatively high at the placenta end. They concluded that it makes the free loop of the umbilical artery the preferred site of choice in the measurement of UbA Doppler indices.

In this study, we noted that all fetuses had three umbilical vessels of two arteries and one vein. No anatomical variation was observed. This may be responsible for the normal health status of the fetuses and the absence of maternal pregnancy complications in our study. Our study observed gradual reduction in UbA Doppler indices (RI, PI, and S/D ratio) from 11 weeks 0 days – 30 weeks 6 days (RI= 0.87 - 0.65, PI= 2.53 - 01.05 and S/D ratio =16.42 - 2 .84) with a resultant increase in values of PSV and EDV (PSV= 41.37 - 64.86 cm/s and EDV=16.27 - 20.93 cm/s) respectively. This finding is similar to that of Acharya et al (22) who reported a reduction in the values of PI, RI, and S/D ratio and an increase in PSV and EDV values as pregnancy progresses. The mean value of the S/D ratio at 20 weeks GA was 4.0, which was reduced to 2.83 at 30 weeks and further reduced to 2.18 at 40 weeks Ga. The RI mean values decrease from 0.87 to 0.65 (11weeks 0days – 30 weeks 6 days). Other

previous studies reported decreases in UbA for RI, PI, and S/D with an increase in GA with normal placenta and normal trophoblastic invasion (25,26). This was explained to be due to an increase in the number of tertiary stem villi and placenta maturation. Thus, as the fetal age progresses, the impedance to blood flow normally reduces, and diastolic blood flow increases in a healthy placenta.

Our study was from 11 weeks – 30 weeks 6 days because placentation is a dynamic and progressive process that starts from the first trimester to the third trimester, and it depends on adequate maternal blood flow to and from the placenta. The Doppler evaluation of the fetal umbilical artery velocimetry and waveform early enough in pregnancy will play a valuable role in the early identification of normal blood flow/waveform from abnormal blood flow/waveform, and the likelihood of development of pregnancy complications such as pre-eclampsia and intrauterine growth restriction. It is, therefore, very important for the practitioner to be able to determine whether the flow/waveform is normal or abnormal for early identification of a fetus/mother that is doing well or not doing well in pregnancy to enhance early detection of pregnancy complications. Also, will be of greater advantage to the clinicians to determine fetus and mother to be placed on surveillance. Thus, early presentation of pregnant women for Doppler ultrasound examination will allow the health and medical experts to determine the fetus and mothers at high risk of complications and decide on choices of timely intervention.

Our study observed a higher value of UbA indices for EDV, PI, and RI in female fetuses than in male fetuses, although not statistically significant. The S/D ratio is the same in male and female fetuses. Our finding agrees with Widnes et al (27) who reported 2–8% higher values of UbA Doppler indices in female than in male fetuses from 20-36 weeks GA but not later. This finding further reinforces our recommendation for the use of the Local Population Reference Values (LPRV), derived from our study, for the evaluation of fetal umbilical artery Doppler indices in pregnancy in our locality. Because African populations are ethnically

different from Western populations and hence there is a need to develop the reference range for our Local Population.

Our study further showed that female fetuses had higher value of heart rates than male fetuses. This was also reported by Widnes et al (27) in their study, which concluded that female fetuses had higher value of heart rates than male fetuses from 26 weeks GA until term.

**Conclusion:** Our study established Doppler indices for umbilical artery in normal pregnancies in a Nigeria population from 11 weeks 0 days to 30 weeks 6 days of gestation. The UbA values from our study should serve as baseline reference values during the Doppler evaluation of the umbilical arteries. It is our belief that data from this study will be invaluable to sonographers, obstetricians, and researchers for the prediction and management of pregnancy outcomes in a similar population.

**Limitations of the study:** A small number of volunteers were enrolled in this pilot study, and we anticipate possible minor variations with a larger sample size in the main thesis. Additionally, participants were not entirely comfortable with transvaginal scans, which constitutes a significant limitation to this study.

**Conflict of interest:**

There are no conflicts of interest.

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