Implementation of WHO Fetal growth charts in Assiut, Egypt

Original Article

Hany Abdelaleem Ali Mahmoud, Dina Mohammed Elsayed Habib, Mostafa Hussein, Sherif Badran and Mina Eshak Tawfeek Khalil

Department of Obstetrics and Gynecology, Assiut University Hospital, Faculty of Medicine, Assiut University, Egypt

ABSTRACT

Background & Aim: Measurement of fetal biometry in the second and third trimesters is an important part of these examinations and biometric measurements are combined routinely in order to calculate the estimated fetal weight (EFW). EFW is a useful parameter with which to predict birth weight and outcome when it is calculated a few days before delivery. The current study aimed to test how well the WHO fetal growth charts help to monitor fetal growth in our setting.

Methods: A total of 200 women were enrolled between November 2018 and December 2019, with data collection being completed with the last childbirth in February 2020. Ninety three cases were excluded so, a total of 107 women were recruited for the analysis. The first visit were between 8+0 and 12+6 weeks, and subsequent visits for fetal biometry were scheduled at approximately 4 weekly.

Results: Mean (± SD) age of enrolled women was 29.35 (5.71) years with range between 19 and 38 year and 104 (97.2%) of cases had living babies at time of delivery while only three cases had neonatal death. Fetal sex had no effect of fetal birth weight. WHO charts and birth weight had insignificant difference as regard SGA and average for gestational age but WHO charts overestimated the frequency of LGA. Hadlock formula and birth weight had insignificant difference as regard frequency of LGA while both of them had significant difference regarding SGA and average for gestational age.

Conclusion: In case of normal fetal growth and cases with suspected growth restriction, WHO charts are better to be used while in cases with suspected macrosomia, Hadlock formula is better to be used.

Key Words: Charts, growth, who.

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Corresponding Author: Mina Eshak Tawfeek Khalil, Department of Obstetrics and Gynecology, Assiut University Hospital, Faculty of Medicine, Assiut University, Egypt, **Tel.:** +2 012 7491 0792, **E-mail:** mina_elbasha2010@yahoo.com

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INTRODUCTION

Birthweight (BWT)- and estimated fetal weight (EFWT)-for-gestational-age charts have long been used as the cornerstone of fetal growth assessment. Fetuses with a weight below a certain statistical threshold of the population, usually the 10th percentile (or less frequently, the 5th or 3rd), are classified as small for gestational age (SGA), and considered to be at increased risk of adverse outcomes due to fetal growth restriction[1].

There are charts are used as reference charts, which are descriptive charts of how fetuses actually grow. In the past 6 years, three new methodologically rigorous fetal growth charts have been published: the World Health Organization (WHO)[2] and INTERGROWTH-21st[3] charts derived from multijurisdictional international populations, and the US National Institute for Child Health and Development (NICHD) fetal growth charts derived from multistate US populations[4].

These charts were derived from selected populations of healthy, low-risk pregnancies, producing prescriptive charts of how fetuses ought to grow (known as standards). From a theoretical perspective, charts that reflect the growth of fetuses under optimal conditions should be better for monitoring fetal growth and identifying fetuses whose growth is failing. Thus, their status as standards, rather than references, is viewed as an important reason for adopting the new charts[5].

The current study aimed to test how well the WHO fetal growth charts help to monitor fetal growth. Also, to assess any difference in the prevalence of fetal growth abnormalities between the WHO fetal growth charts and the growth charts that is currently in use.

PATIENT AND METHODS

Study setting and design

A prospective validation cohort study was conducted at the Antenatal Care (ANC) Clinic of Women's Health Hospital

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Participants

The study recruited any pregnant woman came for ANC Clinic with the following criteria; age between 18-40 year, body mass index (BMI) between 18-30 kg/m^2, singleton pregnancy, gestational age at entry is between 8+ 0 to 12+ 6 week based on last menstrual period (LMP) with reliable date

Also, those women hadn't history of health, environmental or economic constraints likely to impair fetal growth, long-term medication (including fertility treatment); smoking currently or in the previous 6 months; recurrent miscarriage; and any previous baby delivered pre-term (<37 weeks) or with a birth weight < 2,500g

Any woman with multiple pregnancy or congenital fetal malformation (cardiac, cerebral, renal malformations, etc.) in subsequent examination in further visits was excluded

Sample Size Calculation

A minimum of 102 patients were included in this study. This number was calculated based on; 1) population size (for finite population correction factor or fpc) (N):1000 (eligible women within six months), 2) hypothesized % frequency of outcome factor in population (p):8%+/-5 (incidence of intrauterine growth retardation, IUGR), confidence limits as % of 100(absolute +/- %) (d):5% Equation. Results from OpenEpi, Version 3, open source calculator— SSPropor[6].

Study tools

Women in the first trimester were approached by the researcher and asked to participate. Women were fully informed about the study objectives and procedures. Only women who signed a consent form were enrolled into the study

Examination in each visit done by ultrasound type: Voluson E8, RAB6 Volume abdominal Probe. An ultra-light volume probe that is 40% lighter* with ergonomic grip and a thin lightweight cable allowing for easy acquisition of images was used.

We also took maternal measurement e.g.: weight, height, BMI. Also, feeding habits, and any medications took before were recorded. Fetuses were scanned in the first trimester for the estimation of gestational age and subsequently at monthly intervals for fetal biometry. All newborns were received a complete anthropometry assessment after delivery, including measurement of BWT.

At each visit, collection of any information related to pathological processes that may affect fetal growth, and blood pressure and proteinuria were measured. No additional procedures were added to routine antenatal care with the exception of 4-5 additional ultrasonographic examinations.

Pregnant women suspected to have fetal growth abnormalities were assessed both clinically and by ultrasound to confirm if there is IUGR (EFWT <10th centile for gestation age) or fetal macrosomia (EFWT > 90th centile for gestation age). They received the appropriate management according to local protocols and were followed more frequently every 2 weeks till the end of the35th week, then every week till delivery or termination of pregnancy if indicated.

Dating by Ultrasound

Gestational age was confirmed by measuring the crown-rump length (CRL) between 8+0 to 12+6 weeks based in LMP. Gestational age (GA) by CRL should agree with GA by LMP to within 7 days.

To acquire the CRL measurements, the midline sagittal section of the whole fetus was visualized with the fetus horizontal on the screen at 90 degrees to the angle of insonation. GA was assessed by using the reference charts published by Robinsons and Fleming (1975) and by WHO charts[2].

Fetal biometry

The first visit were between 8+0 and 12+6 weeks, and subsequent visits for fetal biometry were scheduled at approximately 4 weekly (+/- 1 week) intervals at 14, 18, 24, 28, 32, 36, and 40 weeks.

All participants were scanned in the lateral recumbent position. The compulsory ultrasound measurements to be obtained at all visits include the following biometrical parameters: biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL) and humerus length (HL).

At each examination, all measurements were obtained three times from three separately generated ultrasound images. The mean of the three measurements of each parameter was used for clinical management purposes as per local protocols. In addition, a full morphological evaluation was conducted at 18-24 weeks. Suspicious of any minor abnormalities was managed according to local clinical guidelines. If the clinical decision was to continue with the pregnancy the case remained in the study. Fortunately, no cases were excluded from the study because of this.

After delivery: Birth weight was measured within 24 hours of delivery. Measurement of neonatal weight was done. According to WHO measurement protocols[7].

Research outcome measures

a. Primary (main)

- Percentiles for estimated fetal weight during gestation weeks 14 to 40 weeks were compared using WHO charts and Hadlock formula.
- Proportion of fetuses with abnormal fetal growth diagnosed using WHO fetal charts and its correlation with neonatal birth weight and outcome.

b. Secondary (subsidiary)

- Numbers of women recruited, those withdrawing consent, those lost to follow-up, and those having miscarriages or intrauterine deaths,
- Women's characteristics
- Delivery information and outcome
- Estimated birthweight percentiles for female and male neonates

Statistical tests

Descriptive statistics were calculated for the women's characteristics at study entry, for mode of delivery, for birth events, and for fetal, neonatal, and maternal conditions. Categorical data were presented as proportion and continuous data as mean + SD.

The frequencies of fetal biometric measurements at each gestational age were compared using the WHO fetal growth charts and Hadlock formula. The observed fetal weight centiles were compared with those expected using WHO fetal growth charts and Hadlock formulas. Chi square test were used for comparison of the proportions. Statistical significance were achieved if $P<0.5$

Ethical consideration

Informed consent form was signed by women agreed to participate in the study. Women who consented to participate was informed about the study. They have the right to withdraw at any time without affecting their management. This study was approved by the Ethical committee of Faculty of medicine Assiut University (11th December, 2018).

RESULTS

A total of 200 women were enrolled between November 2018 and December 2019, with data collection being completed with the last childbirth in February 2020. Eighty two were excluded secondary to history of low birth weight (n= 10), history of recurrent miscarriage (n= 27), history of preterm labor (n= 30), and multiple pregnancies (n= 15). Another three women refused to participate in the study. During follow up; three women were lost and another five women had miscarriage. So, a total of 107 women were recruited for the analysis (Figure 1).

Baseline characteristics of participating women (Table 1)

Mean (± SD) age of enrolled women was 29.35 (5.71) years with range between 19 and 38 year. Up to 30% of the women were 25-< 30 years old. It was found that 69 (64.4%), and 38 (35.4%) women had normal BMI and overweight, respectively.

Only 11 (10.3%) cases of the studied women had current medical diseases in the form of gestational DM (six cases), cardiac disease (four cases), preeclampsia (one case), anaemia (one case) and chest disease (one case)

Mode of delivery and birth outcome based on gestational age

It was found that 104 (97.2%) of cases had living babies at time of delivery while only three cases had neonatal death. Out of the babies; 70 (65.4%) babies were males and 37 (34.6%) babies were females. As regard mode of delivery, 34 (31.8%) women had normal delivery while planned CS was performed for 53 (49.5%) women. The other 20 (18.7%) women had emergency CS.

Birth weight based on fetal sex

Fetal sex had no significant impact on fetal birth weight, frequency of small for gestational and large for gestational age.

Mean percentiles of EFW at gestational ages 14-40 ws calculated by Hadlock formula and WHO growth charts (Table 2)

There is no significance difference between estimated fetal weight by Hadlock formula, and by WHO growth charts at 5th, 10th, and 25th percentiles while there were significant differences at 50th, 75th, 90th and 95th percentiles.

Comparison of Proportion of fetuses with abnormal fetal growth (IUGR and macrosomia) diagnosed using Hadlock formula, WHO fetal growth charts and neonatal birth weight (Table 2)

It was found that WHO charts and birth weight had insignificant difference as regard SGA and average

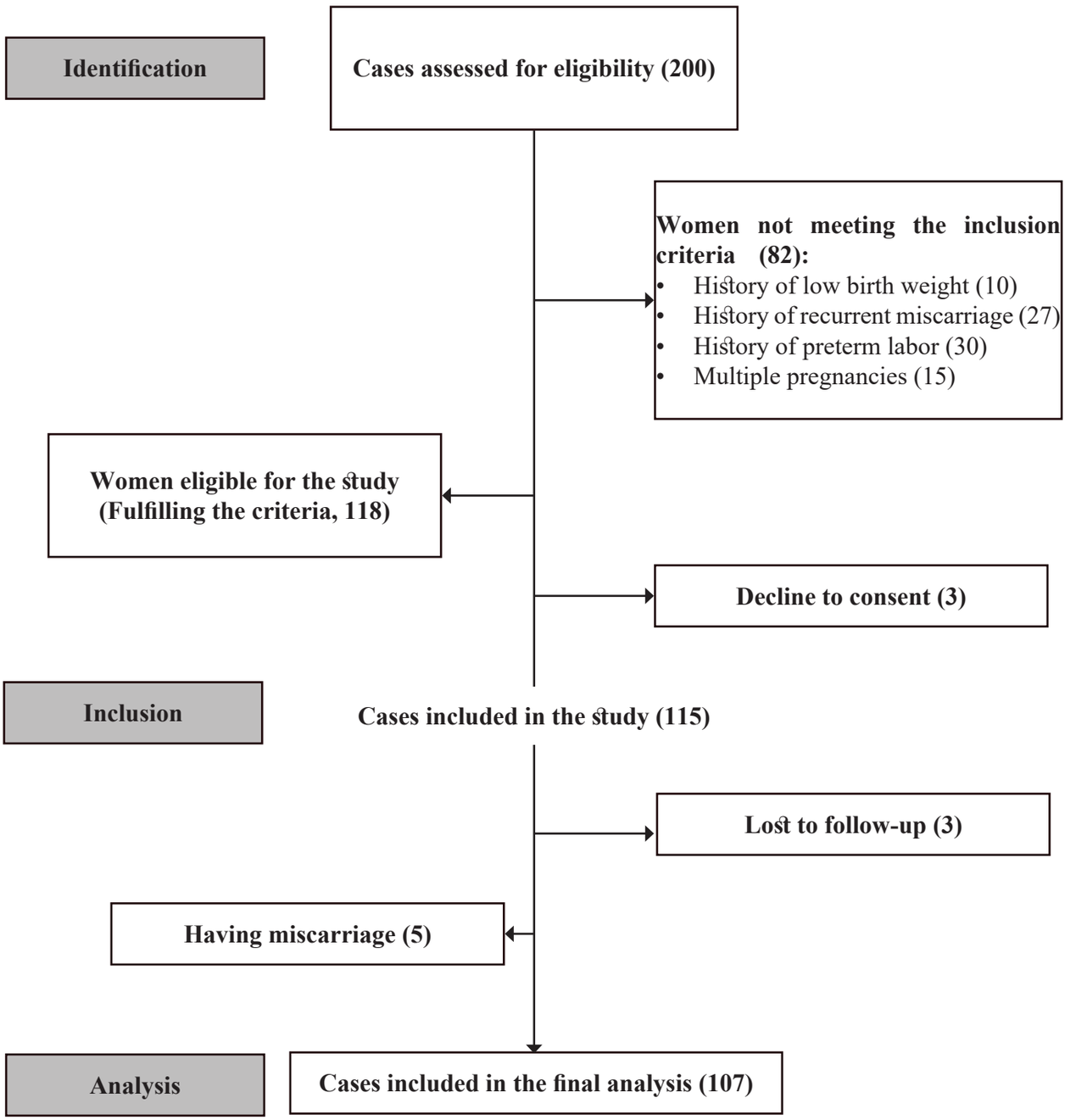

Fig. 1: Flow chart of the current study

for gestational age but WHO charts overestimated the frequency of LGA. Hadlock formula and birth weight had insignificant difference as regard frequency of LGA while both of them had significant difference regarding SGA and average for gestational age

Neonatal outcome in relation to fetal growth pattern diagnosed using WHO fetal charts

Sixty nine (64.4%) neonates were living neonates. While neonatal mortality occurred in 10 (9.3%) neonates (six cases died from respiratory failure, and the cause of death was unknown in four cases).

It was noticed that 22 (20.5%) neonates had morbidity in form of hyperbilirubinemia (7 cases) and difficult breathing (15 cases). Sixteen neonates (15%) were admitted to NICU secondary to hyperbilirubinaemia (7 cases), RDS (4 cases), congenital anomalies (one case had fallot tetralogy) and neonatal sepsis (2 cases).

Mean BPD percentiles at gestational ages14-40 ws calculated by Hadlock formula and WHO growth charts (Table 3)

It was found that there were statistically significant differences between Hadlock formula and WHO growth charts as regard mean BPD percentiles at gestational ages 14-40 weeks with exception at 10^{th} percentile.

Mean percentiles of HC at gestational ages 14-40 ws calculated by Hadlock formula and WHO fetal growth charts (Table 4)

It was found that there were statistically significant differences between Hadlock formula and WHO growth charts as regard mean HC percentiles at gestational ages 14-40 weeks except at 95^{th} percentile.

Mean percentiles of AC at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts (Table 5)

It was found that there were statistically significant differences between Hadlock formula and WHO growth charts as regard mean AC percentiles [5^{th}, 10^{th}, and 25^{th}], while there were no significant differences at 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentile.

Mean percentiles of FL at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts (Table 6)

It was found that there were statistically significant differences between Hadlock formula and WHO growth charts as regard mean FL percentiles at gestational ages 14-40 weeks.

Mean percentiles of HL at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts (Table 7)

It was found that there were statistically no significant differences between Hadlock formula and WHO growth charts as regard mean HL percentiles at gestational ages 14-40 weeks.

Table 1: Mean percentiles of EFW at gestational ages 14-40 ws calculated by Hadlock formula and WHO growth charts

		GA (weeks)																										
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	--	--	1.2	--	--	2.2	--	--	--	--	3.6	3.6	--	--	--	--	--	1.6	--	2.3	4.2	--	--	2.6	--	--	--	1.000
	WHO	2.5	3.6	2.5	2.5	3.1	3.1	2.5	2.7	2.5	2.5	3.8	2.5	2.5	2.6	2.5	3.0	2.5	3.1	2.5	3.0	3.0	3.3	3.7	2.5	2.5	2.5	--	
10th	Hadlock	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.3	--	--	--	--	--	--	--	--	--	6.2	--	--	0.893
	WHO	7.9	9.8	6.3	7.0	--	7.1	9.7	5.3	--	7.5	--	6.8	8.3	--	--	8.9	5.2	--	--	6.4	6.8	--	8.4	--	8.9	--	7.1	
25th	Hadlock	14.5	16.6	17.5	--	24.4	10.2	15.7	--	12.3	19.0	--	--	23.5	22.2	--	--	21.0	20.0	21.1	18.5	19.8	11.1	15.0	22.6	17.3	14.1	14.7	0.717
	WHO	--	17.6	20.7	14.1	23.0	14.9	14.5	10.9	22.5	12.9	19.1	16.4	11.7	15.9	--	--	--	13.4	22.8	17.5	14.8	16.5	15.9	23.7	17.0	14.5	--	
50th	Hadlock	33.4	35.5	36.7	32.5	34.0	38.4	32.5	37.0	39.3	33.2	40.3	41.9	38.9	36.2	32.0	35.8	34.6	39.1	41.2	36.6	42.2	33.8	38.4	44.4	39.1	--	42.1	0.013*
	WHO	34.9	42.9	40.2	48.9	36.6	43.7	41.7	40.3	40.8	36.1	37.9	41.3	37.6	--	39.5	37.4	32.1	38.9	29.3	46.3	44.9	34.1	39.4	43.1	38.0	--	43.2	
75th	Hadlock	60.3	--	63.5	67.3	60.8	--	61.7	66.6	60.9	73.0	64.1	57.7	64.0	59.2	62.0	62.2	67.3	60.9	64.1	60.9	62.6	62.6	65.2	65.5	70.7	--	59.9	0.000*
	WHO	64.1	65.0	66.2	64.0	56.6	53.4	63.8	66.3	70.6	--	64.7	55.5	50.4	60.8	58.7	60.2	63.9	59.0	57.9	61.7	74.9	63.5	64.3	62.8	64.0	--	--	
90th	Hadlock	--	88.3	83.0	78.2	--	--	88.3	83.2	--	--	76.6	88.9	--	77.2	82.6	80.1	82.7	85.4	--	81.0	83.0	86.3	82.8	80.4	--	--	--	0.000*
	WHO	82.3	81.0	81.0	80.7	85.0	76.0	78.2	85.9	81.0	--	80.5	79.7	84.2	76.7	83.1	81.2	79.3	84.8	77.0	81.2	86.9	78.2	84.5	84.9	75.9	--	--	
95th	Hadlock	--	--	95.3	92.8	--	--	92.6	90.2	94.2	--	94.2	--	--	--	92.2	90.0	--	94.2	90.0	90.0	--	92.1	90.0	90.0	--	--	--	0.000*
	WHO	97.5	93.2	96.0	96.7	94.9	94.7	92.2	93.7	93.9	97.5	94.4	92.5	95.6	94.8	96.5	96.8	94.3	96.8	93.0	95.4	95.8	95.7	93.8	92.9	--	--	91.4	

Data expressed as mean. *P value* was significant if < 0.05. WHO: world health organization; GA: gestational age

Table 2: Comparison of Proportion of fetuses with abnormal fetal growth diagnosed using Hadlock formula, WHO fetal charts and neonatal birth weight

	WHO charts No. (%) (107)	Hadlock formula No. (%) (107)	Birth weight# No. (%) (107)	*P-value*1	*P-value*2
SGA [< 10th centile]	11 (10.28)	3 (2.8)	19 (17.8)	0.115	0.000*
LGA [>90th centile]	14 (13.0)	3 (2.8)	2 (1.9)	0.002*	1.000
Average for gestational age	82 (76.6)	101 (94.4)	86 (80.4)	0.506	0.002*

Data expressed as number (percentage),). *P value* was significant if < 0.05. SGA: small for gestational age; LGA: large for gestational age; WHO: world health organization

Birth weight centiles were calculated using WHO charts, (104)

*P-value*1: Comparison between estimated fetal weight according to WHO fetal charts and neonatal birth weight

Table 3: Mean BPD percentiles at gestational ages14-40 ws calculated by Hadlock formula and WHO growth charts

		GA (weeks)																										
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	--	2.3	2.3	--	2.3	3.7	3.4	1.5	2.8	2.3	--	--	2.3	2.3	--	2.8	2.8	2.3	2.3	--	3.6	2.4	2.8	--	2.3	2.3	--	0.005*
	WHO	2.5	2.5	2.9	2.5	2.5	2.5	2.5	3.7	2.5	3.1	3.6	--	3.7	2.5	--	2.9	4.3	2.5	2.5	--	3.9	--	3.8	--	2.5	2.5	--	
10th	Hadlock	--	--	9.8	--	--	--	--	--	--	--	--	--	5.9	--	--	--	--	--	--	9.8	5.4	--	8.4	7.6	--	--	--	0.228
	WHO	5.7	--	9.1	--	8.4	7.7	--	8.4	--	7.2	8.3	7.0	--	8.2	5.6	--	--	--	--	--	9.1	6.0	7.4	8.3	--	--	--	
25th	Hadlock	13.9	14.0	20.3	15.3	13.7	16.0	22.6	13.5	22.4	15.2	16.9	17.5	17.5	15.1	15.2	21.7	--	20.7	16.0	18.4	23.1	20.3	15.8	17.5	17.7	19.4	17.0	0.002*
	WHO	13.2	22.3	--	15.6	--	23.2	18.0	--	22.3	23.6	12.1	16.3	23.0	--	16.4	19.3	22.8	20.3	18.0	16.9	24.0	21.1	16.9	20.6	18.8	17.8	14.7	
50th	Hadlock	32.3	39.7	40.7	42.7	45.3	39.6	35.9	42.8	45.2	37.6	44.7	34.9	39.7	45.0	43.3	43.9	47.0	44.8	41.4	37.3	35.9	31.0	39.2	35.4	--	--	46.5	0.003*
	WHO	35.5	37.4	38.0	40.8	43.5	39.5	33.2	39.9	43.7	43.4	40.3	39.4	26.5	35.8	41.4	37.8	45.2	43.8	34.3	40.6	38.5	28.8	35.3	35.5	--	--	47.7	
75th	Hadlock	64.6	58.9	65.0	61.2	63.4	62.4	63.5	68.1	58.3	62.3	64.8	60.3	67.2	--	60.3	65.8	54.1	61.1	56.2	57.7	62.4	64.9	71.0	64.4	60.4	--	--	0.000*
	WHO	57.2	69.5	65.1	61.7	65.1	57.7	62.2	64.3	58.7	61.1	56.7	68.5	55.8	--	66.5	64.7	--	60.4	73.0	65.2	59.0	57.3	66.4	56.1	64.3	--	--	
90th	Hadlock	84.6	82.4	79.4	80.0	77.4	87.8	78.6	78.7	80.9	--	80.3	83.3	84.7	--	87.1	86.6	--	83.5	85.7	83.3	87.6	87.2	81.7	--	86.3	82.2	88.3	0.000*
	WHO	81.9	86.5	80.6	81.4	78.3	87.4	81.7	78.9	89.4	--	81.3	81.1	77.7	--	79.8	81.0	--	82.5	80.9	87.0	78.5	80.4	83.6	89.6	78.1	87.2	89.7	
95th	Hadlock	--	97.3	94.2	94.2	97.0	90.1	96.3	94.4	92.7	--	95.8	94.9	98.7	97.7	96.3	94.7	97.7	95.7	93.7	95.8	90.5	95.7	95.4	94.4	--	--	--	0.000*
	WHO	97.5	95.6	96.5	96.4	97.5	--	97.2	94.1	--	--	97.0	90.5	--	95.2	97.5	97.2	94.7	96.1	96.4	94.3	--	94.7	94.4	96.3	90.4	--	--	

Data expressed as mean. *P value* was significant if < 0.05. WHO: world health organization; GA: gestational age

Table 4: Mean percentiles of HC at gestational ages 14-40 ws calculated by Hadlock formula and WHO fetal growth charts

		GA (weeks)																											
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	4.4	2.3	1.9	2.4	2.3	2.4	3.3	3.0	2.7	3.1	3.0	3.2	2.8	2.3	--	3.5	2.3	3.2	2.7	2.7	2.5	2.3	2.3	2.5	2.9	2.6	2.3	0.000*
	WHO	2.7	2.5	2.5	2.5	2.5	2.6	3.0	3.5	3.9	3.1	3.7	3.6	3.2	2.5	3.2	2.6	2.5	2.5	5.0	2.9	3.0	3.1	3.2	2.5	2.5	2.5	4.8	
10th	Hadlock	5.8	5.3	--	--	6.6	5.6	7.1	9.9	--	6.4	7.0	5.5	8.2	9.6	7.1	8.0	--	6.7	--	8.3	6.3	5.8	7.7	--	8.4	--	--	0.000*
	WHO	--	6.8	8.0	--	--	6.1	9.2	9.1	8.2	8.9	--	5.2	9.9	8.2	8.9	7.7	--	7.0	6.4	9.8	6.6	9.5	5.7	9.6	--	--	--	
25th	Hadlock	--	13.0	17.3	18.5	15.1	15.8	14.1	11.1	24.9	13.5	18.2	19.4	14.6	22.9	17.3	19.3	11.0	15.1	--	19.7	17.7	--	15.8	18.9	22.6	--	--	0.000*
	WHO	20.4	21.8	16.5	16.9	18.7	16.8	18.2	14.4	22.1	21.0	17.4	21.2	14.9	--	17.8	18.8	21.5	20.0	20.6	17.7	17.1	14.4	16.4	12.1	20.1	15.4	15.9	
50th	Hadlock	38.7	41.6	32.6	27.4	40.1	33.0	37.5	36.5	38.3	40.6	38.1	34.8	38.4	39.0	34.2	29.7	37.2	31.2	40.8	35.7	40.4	30.0	33.2	40.1	33.4	--	48.9	0.001*
	WHO	--	40.9	35.3	39.1	33.3	39.2	36.1	42.9	38.9	43.3	29.2	30.7	39.1	35.3	39.5	32.0	39.7	41.6	43.6	31.9	38.1	29.1	35.1	41.7	28.1	--	49.3	
75th	Hadlock	68.0	56.6	57.0	61.6	65.5	59.4	59.7	60.7	64.4	--	64.3	54.6	60.7	58.9	68.8	56.8	51.0	67.1	65.6	52.5	62.0	57.0	64.0	51.7	68.5	--	72.2	0.026*
	WHO	57.2	60.6	63.4	65.7	57.6	60.3	64.9	61.1	65.8	66.1	62.1	52.2	65.3	66.1	70.1	64.3	60.3	56.3	62.4	59.0	63.8	69.7	59.0	67.1	65.1	--	73.2	
90th	Hadlock	80.0	85.7	87.2	82.8	--	81.9	81.1	81.4	79.3	77.4	78.7	80.1	87.3	--	76.6	79.3	85.7	83.2	--	80.7	--	83.9	87.2	86.2	--	--	--	0.000*
	WHO	75.2	84.5	82.3	81.3	82.9	84.7	81.1	82.4	80.7	88.3	81.4	82.1	89.5	--	81.7	83.5	--	82.8	81.9	82.6	79.7	80.4	79.7	81.5	--	--	--	
95th	Hadlock	--	93.1	94.9	94.2	93.6	--	--	--	--	--	95.1	--	--	--	95.0	96.8	--	93.1	94.4	96.1	94.5	95.2	94.2	--	--	--	--	0.121
	WHO	97.5	94.4	95.4	96.9	97.5	92.0	--	--	91.8	--	97.4	90.9	--	--	--	97.4	90.6	97.5	96.5	94.0	--	92.3	96.2	97.5	--	--	--	

Data expressed as mean. *P value* was significant if < 0.05. WHO: world health organization; GA: gestational age

Table 5: Mean percentiles of AC at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts

		GA (weeks)																										
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	--	3.8	1.6	--	--	3.7	2.3	--	2.3	--	3.2	2.5	2.3	2.7	4.5	2.5	--	3.1	2.5	2.6	2.4	2.3	2.6	2.3	2.3	2.3	2.3	0.021*
	WHO	2.5	2.5	2.7	2.5	--	3.4	3.7	3.4	2.5	4.5	4.0	3.6	2.5	2.5	2.5	2.5	--	2.5	2.5	2.8	3.1	3.1	3.3	2.6	2.5	2.5	2.7	
10th	Hadlock	--	7.0	--	--	8.3	5.1	--	7.9	6.9	9.2	--	--	--	--	--	8.8	8.8	--	--	--	7.6	--	8.4	--	7.1	--	--	0.050*
	WHO	7.9	8.8	--	--	8.5	5.9	7.7	--	6.7	6.6	5.3	7.4	5.5	8.4	--	7.9	9.5	7.3	--	8.1	--	6.3	9.3	--	--	--	--	
25th	Hadlock	15.2	--	14.5	15.0	21.3	16.1	16.9	19.0	--	14.7	16.5	14.8	19.6	12.7	17.4	12.9	--	--	24.2	15.3	15.6	12.9	16.9	10.3	13.0	16.1	12.1	0.015*
	WHO	17.8	14.4	17.9	14.7	18.4	21.1	18.5	17.2	16.3	17.7	22.7	22.9	18.0	--	15.1	17.3	--	--	20.3	20.3	18.1	18.3	20.4	11.1	15.0	15.8	13.1	
50th	Hadlock	35.6	44.1	35.3	34.0	39.9	43.0	38.3	36.2	34.2	33.6	35.4	40.8	43.3	--	29.3	37.3	40.9	37.4	34.9	34.6	37.7	27.2	40.6	43.9	31.8	--	36.9	0.261
	WHO	37.6	36.8	40.3	--	42.4	43.5	37.1	40.1	36.6	--	41.5	40.2	37.4	45.4	28.7	43.1	38.9	40.6	36.5	39.2	35.3	28.1	43.3	46.3	35.6	--	32.9	
75th	Hadlock	64.3	62.8	62.6	67.0	57.8	64.7	63.4	55.6	60.6	--	64.6	--	73.9	60.9	61.7	65.6	71.6	73.5	65.4	64.7	62.0	59.6	64.4	64.2	61.3	--	70.2	0.991
	WHO	59.3	59.2	62.8	65.3	61.8	65.2	64.9	59.7	60.0	--	66.9	69.2	--	62.7	61.6	63.2	--	72.6	61.2	62.6	64.1	57.3	61.4	60.7	69.5	--	71.2	
90th	Hadlock	85.6	83.3	81.0	82.3	81.0	81.3	80.4	85.1	81.7	83.2	85.1	81.9	82.7	--	87.7	80.1	81.4	87.3	80.2	84.0	81.5	87.4	82.8	86.5	--	--	--	0.481
	WHO	79.4	84.6	80.3	80.9	85.4	86.3	82.8	87.0	82.1	79.9	80.3	84.3	77.8	--	85.8	79.8	81.9	81.0	75.3	84.9	79.0	81.9	76.9	83.4	78.9	--	--	
95th	Hadlock	95.8	96.0	94.0	93.8	94.4	91.4	92.3	93.2	93.4	94.8	91.5	--	93.3	96.0	95.0	95.9	93.0	97.7	94.6	95.5	97.3	95.6	96.3	95.1	94.4	--	--	0.925
	WHO	94.2	94.6	96.4	96.1	96.1	95.4	94.1	96.2	97.1	95.8	92.6	93.0	95.2	96.3	95.5	96.1	93.0	97.5	94.1	96.7	96.2	96.5	94.1	95.1	--	--	--	

Data expressed as mean. *P value* was significant if < 0.05. WHO: world health organization; GA: gestational age

Table 6: Mean percentiles of FL at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts

		GA (weeks)																										
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	2.7	2.3	--	2.3	--	3.0	3.7	2.3	2.3	2.7	--	--	--	--	--	--	2.8	--	3.5	2.0	3.4	2.5	--	4.7	2.8	4.4	--	0.000*
	WHO	2.6	3.3	2.5	2.5	--	3.7	2.5	2.5	2.5	2.5	--	--	--	--	--	--	2.5	--	--	2.8	2.5	3.6	3.4	--	2.5	--	--	
10th	Hadlock	6.3	7.1	9.6	8.7	--	5.2	--	5.6	--	7.5	9.3	--	--	--	6.4	--	--	--	6.2	6.5	7.7	7.0	7.8	--	5.3	--	--	0.000*
	WHO	--	--	9.1	8.3	9.1	6.6	--	--	--	7.3	9.4	--	--	9.2	9.3	8.8	7.0	--	6.3	--	7.9	--	--	--	5.8	--	--	
25th	Hadlock	24.3	21.7	18.6	15.5	11.7	18.5	20.2	17.4	16.0	18.7	19.7	19.6	19.2	13.1	10.6	20.8	--	17.6	21.9	15.4	14.7	21.6	14.2	16.4	12.3	16.6	15.9	0.000*
	WHO	14.6	12.6	--	13.9	23.7	18.6	17.0	13.4	10.2	17.8	18.4	22.3	15.5	18.1	11.6	--	--	--	20.5	14.9	21.8	15.8	21.0	14.7	12.7	--	--	
50th	Hadlock	39.9	37.8	37.9	38.2	27.0	36.4	38.4	39.5	37.7	--	34.0	32.7	33.1	34.4	32.3	39.9	38.4	41.7	38.1	34.0	36.6	43.5	38.5	39.6	36.1	--	--	0.000*
	WHO	35.8	37.5	38.3	36.0	33.3	42.2	36.1	40.3	36.7	25.9	37.3	32.7	32.0	--	39.1	37.2	--	42.1	41.9	40.1	34.9	44.2	33.3	37.0	40.8	28.0	--	
75th	Hadlock	62.7	58.9	62.2	61.8	62.8	58.8	61.9	64.6	58.9	--	67.5	66.4	67.9	61.7	63.5	54.9	56.0	64.2	63.6	63.6	59.0	69.1	63.3	67.8	63.7	--	59.6	0.000*
	WHO	50.5	59.2	61.3	60.0	68.2	65.8	61.2	65.7	63.3	--	56.1	66.7	67.8	51.6	59.8	61.5	60.6	68.6	62.5	62.0	59.7	60.6	58.0	64.0	63.7	52.9	65.3	
90th	Hadlock	83.9	80.0	82.2	81.0	80.7	81.4	81.8	84.9	83.3	84.7	84.3	85.4	85.5	80.6	85.1	85.8	90.0	81.9	--	76.9	82.5	89.9	85.8	76.3	--	--	--	0.000*
	WHO	82.5	80.5	78.7	77.0	81.9	84.2	80.8	83.1	79.6	--	75.7	81.0	82.1	77.8	82.6	81.5	86.7	82.5	83.0	81.3	80.4	81.4	82.9	80.6	81.8	--	--	
95th	Hadlock	--	90.5	95.3	95.3	91.4	--	--	91.2	--	91.2	95.4	--	94.7	--	96.2	93.5	95.1	95.9	94.8	93.2	94.6	96.3	97.7	--	--	--	94.7	0.000*
	WHO	94.5	94.2	97.2	96.1	94.5	93.9	95.0	96.3	95.4	96.6	95.6	96.2	96.0	96.0	95.9	97.2	97.5	97.0	97.5	96.2	96.7	97.2	96.5	--	--	--	96.4	

Table7: Mean percentiles of HL at gestational ages 14-40wks calculated by Hadlock formula and WHO fetal growth charts

		GA (weeks)																										
		14 (17)	15 (21)	16 (25)	17 (18)	18 (13)	19 (16)	20 (25)	21 (17)	22 (14)	23 (10)	24 (21)	25 (15)	26 (13)	27 (8)	28 (13)	29 (20)	30 (9)	31 (17)	32 (10)	33 (27)	34 (18)	35 (16)	36 (22)	37 (12)	38 (9)	39 (3)	40 (4)	*P- value*
5th	Hadlock	4.7	4.8	--	5.0	--	--	--	--	--	--	5.0	--	--	--	--	--	--	--	5.0	5.0	5.0	5.0	5.0	--	5.0	5.0	5.0	0.239
	WHO	2.5	2.5	3.5	3.3	--	4.9	2.5	4.9	--	4.3	3.2	--	--	--	--	2.5	--	--	2.5	3.0	2.5	2.5	2.5	--	2.5	--	--	
10th	Hadlock	5.3	--	7.7	9.9	--	--	7.2	--	--	--	9.4	--	--	--	--	--	--	--	--	--	8.3	--	--	--	--	--	--	0.818
	WHO	--	8.7	--	--	--	6.8	9.6	8.1	--	6.1	.	--	--	--	--	--	--	--	10.0	--	--	5.8	--	--	--	7.9	--	
25th	Hadlock	--	13.4	18.0	18.1	--	19.1	17.2	20.3	--	20.4	22.4	--	19.6	--	--	24.2	24.6	--	15.5	20.1	18.5	23.4	16.1	--	23.9	--	--	0.104
	WHO	24.1	13.8	15.1	15.5	14.9	19.8	18.0	16.3	24.1	22.8	21.3	14.9	13.3	--	24.8	--	25.0	--	14.9	22.3	19.0	24.7	15.3	--	--	19.4	23.7	
50th	Hadlock	33.8	36.7	40.6	49.3	36.3	36.8	41.0	37.4	44.8	43.0	39.6	43.5	37.9	38.3	32.7	34.0	40.6	32.0	49.5	41.1	40.8	32.6	36.0	36.4	33.5	40.5	--	0.965
	WHO	36.7	34.9	37.5	49.7	37.5	38.1	43.1	43.9	44.3	33.5	37.5	32.9	29.5	33.7	46.8	31.4	40.3	41.9	28.5	37.3	34.7	29.1	37.0	38.6	36.6	--	--	
75th	Hadlock	--	64.0	63.0	58.2	63.4	58.9	64.1	63.6	71.5	--	62.0	66.8	64.0	65.7	--	61.6	--	63.9	--	66.8	64.8	64.6	66.0	62.0	--	--	74.4	0.389
	WHO	58.5	61.3	63.2	57.3	62.7	58.7	65.4	62.3	60.4	74.3	58.8	66.7	58.7	62.9	--	63.4	--	63.2	74.8	59.3	59.2	61.2	68.1	58.8	--	60.6	--	
90th	Hadlock	84.2	77.4	85.5	85.0	81.0	82.7	82.0	83.2	84.5	76.5	88.5	83.6	84.3	--	85.2	83.1	83.9	78.8	85.3	82.4	77.3	87.9	78.8	84.6	80.7	--	80.2	0.062
	WHO	--	78.3	82.1	88.7	78.4	80.2	78.8	82.2	84.5	--	84.9	81.2	86.2	--	77.3	83.9	80.7	81.2	84.8	82.5	80.2	86.9	77.9	83.9	83.1	--	82.0	
95th	Hadlock	95.0	92.9	94.9	95.3	95.0	94.2	94.0	93.8	91.6	95.1	94.6	93.9	95.0	92.2	94.3	95.3	93.7	92.8	93.5	94.6	93.4	94.4	94.9	95.3	90.6	--	--	0.572
	WHO	96.2	94.7	96.3	94.6	95.9	95.8	94.4	95.7	92.8	97.5	96.4	96.9	96.6	93.0	95.2	96.0	93.7	95.5	96.3	95.9	95.1	95.6	96.5	96.8	--	--	--	

DISCUSSION

In the current study, a total of 200 women were enrolled between November 2018 and July 2019, with data collection being completed with the last childbirth in February 2020. Study participants were recruited from pregnant women attending ANC of Women's Health Hospital. After exclusion of 83 cases due to different causes (Figure1), a total of 107 women were recruited for the analysis with compliance rate 100%.

In WHO, compliance for all countries combined in each gestational age window was between 89.1% and 100%; 72% of the participants had a complete set of all the scheduled scans. In addition, for each of the measurements BPD, HC, AC, FL, and HL, scans were obtained ≥2 times for at least 95% of participants.

Mean age of enrolled women was 29.35 years with range between 19 and 38 years. Median maternal height 157.70 cm. Median maternal weight was 55.64 kg. Based on BMI, it was found that 69 (64.4%), and 38 (35.4%) women had normal BMI and overweight, respectively.

While in WHO study median age at study entry was 28 y but varied between 24 y (Argentina and Egypt) and 32 y (France). Median maternal height ranged from 155 cm (India) to 169 cm (Germany), and weight from 54 kg (Thailand) to 66 kg (Germany). While overall median BMI was 23.1 kg/m^2, the median by country ranged from 21.6 kg/m^2 in Thailand to 25.9 kg/m^2 in Egypt.

The study aimed to assess implementation of WHO fetal growth charts in comparison to Hadlock formula in our setting. The main results of this study showed that fetal sex had no significant effect on fetal weight and frequency of SGA and LGA. Also, fetal weight was accurately estimated by Hadlock formula in comparison to WHO chart at 5th, 10th and 25th percentiles but after 50th percentile there were significant difference between WHO chart and Hadlock formula.

The study also found that Hadlock formula and WHO chart underestimated frequency of SGA while WHO chart overestimated frequency of LGA. In contrast, Hadlock formula was able to estimate frequency of LGA (3 (2.8%) vs. 2 (2.1%); p= 1.000). At the same we found no significant differences between fetuses with average for gestational age and those with abnormal fetal weight as regard neonatal morbidity and mortality.

WHO study revealed that there were three intrauterine deaths and three neonatal deaths, representing a perinatal mortality of 0.4%whiile in our study the perinatal mortality occurred 10 neonates (0.09%). This discrepancy is attributed secondary to different population enrolled in WHO study.

Only 11 (10.3%) cases of the studied women had current medical diseases in the form of gestational DM (six cases), cardiac disease (four cases), preeclampsia (one case), anaemia (one case) and chest disease (one case). One fetal malformation discovered after birth (fallot tetralogy)

In WHO study, in addition to globally experienced maternal complications such as preeclampsia, pregnancy-induced hypertension, gestational diabetes, and anemia, 42 had identified malaria. There was no maternal death. Four small-for-gestational-age fetuses were identified clinically, of which two were examined using Doppler ultrasound; none had abnormal recordings in the umbilical artery or middle cerebral artery, and all were kept in the analysis.

It was registered when neonates needed transmission to the neonatal intensive care unit, commonly due to prematurity, respiratory distress syndrome, infections, or jaundice. There were three intrauterine deaths and three neonatal deaths, representing a perinatal mortality of 0.4%. One malformation was discovered at birth, here counted as fetal malformation.

There were wide variations between Hadlock formula and WHO chart as regard estimated biparietal diameter, head circumference, and femur length but both of them are closely related as regard assessment of abdominal circumference and humerus length. The INTERGROWTH-21st project recommended that, for clinical use, all individual fetal measurements, together with the summary measure of EFW, should be used together to make clinical decisions[3].

Regarding mode of delivery and birth outcome, it was found that 104 (97.2%) of cases had living babies at time of delivery while only three cases had neonatal death. Out of the babies; 70 (65.4%) babies were males and 37 (34.6%) babies were females. As regard mode of delivery, 34 (31.8%) women had normal delivery while planned CS was performed for 53 (49.5%) women. The other 20 (18.7%) women had emergency CS.

In WHO study, most of the countries had a similar distribution between female and male neonates except for Egypt, The incidence of preterm birth varied from 3.6% in Germany to 14.7% in Egypt (p = 0.03 for differences among countries)[2].

In the INTERGROWTH-21st project, data were derived from 2404 live babies without congenital abnormality, who were born within 14 days of an ultrasound scan; women were recruited from urban areas in several countries and had serial ultrasound scans and fetal biometry throughout pregnancy[3].

We noticed that EFW at different percentiles in the current study was considerably higher than those of the

INTERGROWTH-21st and WHO charts. This could be explained as these studies enrolled different populations while we enrolled single population.

Also, such differences are most likely the result of underlying differences in the study populations, demonstrating that the desire for a single international standard for all countries is inappropriate; a single standard would underestimate growth restriction in countries with normal big babies, such as Norway, and overestimate growth restriction in countries with normal small babies.

Interestingly, the 10th percentile for the Intergrowth-21st Project results seems to fall below that of the WHO study[2], even though the Intergrowth-21st Project study[3] was carried out according to a strictly prescriptive concept to establish so-called optimal fetal growth

It was found that all weight centiles were about 2% higher for male than for female fetuses, maternal height had a positive effect on EFW, with larger fetuses being affected more and maternal weight and parity had a positive effect on EFW that increased with gestation and varied among the weight centiles[8]. In our study we found that that fatal sex had no significant effect on fatal weight.

Salomon *et al*., (2007) discovered that, for preterm deliveries, the EFW was significantly greater than the BW[9]. In contrast to our study, the majority of neonates had FW was accurately estimated.

Variation between populations was not restricted to fetal size because there were also differences in growth trajectories. The wide physiologic ranges, as illustrated by the 5th–95th percentile for estimated fetal weight being 2205–3538 g at 37 weeks gestation, signify that human fetal growth under optimized maternal conditions is not uniform. Rather, it has a remarkable variation that largely is unexplained by commonly known factors[3].

There are many reported studies that confirmed the biologically interesting facts that fetal sex and maternal height, weight, parity, and age significantly influence fetal growth. Together with the country differences, the ethnic differences shown in the US population, and, not least, the substantial variation in birthweight among carefully selected low-risk pregnancies, these findings document a diversity and plasticity in human prenatal growth dynamics that is only partially understood[10,11].

In a previous longitudinal observational study, the authors enrolled 2193s weight measurements from 583 fetuses/newborns were included in the fetal weight chart. They concluded that their chart had lower percentiles than all the other charts[12]. They also, stated that the modified Hadlock chart is easy to use, can be applied worldwide, and was the one most similar to their chart. This study was in line to the current study as regarding EFW by the Hadlock formula.

The main limitation of the study; the number of cases that didn't have the chance to deliver at AUH 23 cases (20%),those may make effect on birth weight, but we did post hock analysis after exclusion of these cases and made a comparison between total mean birth weight and mean birth weight after exclusion of these 20 cases. There is no statistically significant differences between them that mean no effect on birth weight.

The main strengths of our study are; 1) limited number of sonographers in study help in decrease the variability in ultrasound fetal measurement between them and increases the accuracy in measurements especially because they are same sonographers who participated in WHO study for fetal growth charts in 2017 from Egypt, 2) prospective nature of the study and 3) sample size that calculated was achieved.

CONCLUSION

In cases with normal fetal growth, WHO charts were more accurate than Hadlock formula in diagnosis of estimated fetal weight in comparison to birth weight, while in cases with abnormal fetal growth, WHO charts in diagnosis of SGA better than Hadlock formula, while the latter was more accurate in diagnosis of LGA in comparison to birth weight.

So, its recommended WHO charts can be used in estimation of fetal weight in cases with normal fetal growth and in cases suspected to have SGA. Hadlock formula can be used in estimation of fetal weight in cases suspected to have fetal macrosomia.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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