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Fetal biometric parameters: Reference charts for a non-selected risk population from Uberaba, Brazil

Alberto Borges Peixoto[1,2], Taciana Mara Rodrigues da Cunha Caldas[1,2], Fernando Felix Dulgheroff[1], Wellington P. Martins[3], Edward Araujo Júnior[4]

[1] *Mario Palmério University Hospital – University of Uberaba (Uniube), Uberaba-MG, Brazil*
[2] *Radiologic Clinic of Uberaba (CRU), Uberaba-MG, Brazil*
[3] *Department of Obstetrics and Gynecology, Ribeirão Preto Medical School, University of São Paulo (DGO-FMRP-USP), Ribeirão Preto-SP, Brazil*
[4] *Department of Obstetrics, Paulista School of Medicine – Federal University of São Paulo (EPM-UNIFESP), São Paulo-SP, Brazil*

Correspondence: Prof. Edward Araujo Júnior, PhD, Department of Obstetrics, Paulista School of Medicine – Federal University of São Paulo (EPM-UNIFESP), Rua Belchior de Azevedo, 156 apto. 111 Torre Vitoria, São Paulo–SP, Brazil, CEP 05089-030, tel./fax: +55 11 37965944, e-mail: araujojred@terra.com.br

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Key words
biparietal diameter, abdominal circumference, femur diaphysis length, estimated fetal weight, reference charts

Abstract

Objective: To establish reference charts for fetal biometric parameters in a non-selected risk population from Uberaba, Southeast of Brazil. **Methods:** A retrospective cross-sectional study was performed among 5656 non-selected risk singleton pregnant women between 14 and 41 weeks of gestation. The ultrasound exams were performed during routine visits of second and third trimesters. Biparietal diameter (BPD) was measured at the level of the thalami and cavum septi pellucidi. Head circumference (HC) was calculated by the following formula: HC = 1.62*(BPD + occipital frontal diameter, OFD). Abdominal circumference (AC) was measured using the following formula: AC = (anteroposterior diameter + transverse abdominal diameter) × 1.57. Femur diaphysis length (FDL) was obtained in the longest axis of femur without including the distal femoral epiphysis. The estimated fetal weight (EFW) was obtained by the Hadlock formula. Polynomial regressions were performed to obtain the best-fit model for each fetal biometric parameter as the function of gestational age (GA). **Results:** The mean, standard deviations (*SD*), minimum and maximum of BPD (cm), HC (cm), AC (cm), FDL (cm) and EFW (g) were 6.9 ± 1.9 (2.3 – 10.5), 24.51 ± 6.61 (9.1 – 36.4), 22.8 ± 7.3 (7.5 – 41.1), 4.9 ± 1.6 (1.2 – 8.1) and 1365 ± 1019 (103 – 4777), respectively. Second-degree polynomial regressions between the evaluated parameters and GA resulted in the following formulas: BPD = –4.044 + 0.540 × GA – 0.0049 × GA² (R^2 = 0.97); HC= –15.420 + 2.024 GA – 0.0199 × GA² (R^2 = 0.98); AC = –9.579 + 1.329 × GA – 0.0055 × GA² (R^2 = 0.97); FDL = –3.778 + 0.416 × GA – 0.0035 × GA² (R^2 = 0.98) and EFW = 916 – 123 × GA + 4.70 × GA² (R^2 = 0.96); respectively. **Conclusion:** Reference charts for the fetal biometric parameters in a non-selected risk population from Uberaba, Southeast of Brazil, were established.

Introduction

Fetal size and fetal growth trajectories are important indicators of fetal health and prenatal ultrasound is a gold-standard. Fetal growth disorders are usually identified based on discrepancies between the actual and expected biometric measurements for a given gestational age[1].

Routine third trimester ultrasound increases the detection rate of small for gestational age (SGA) embryos from 46 to 80% and large for gestational age (LGA) embryos from 36 to 91%, without Doppler ultrasound as proved in a randomized controlled trial[2]. Furthermore, late third trimester ultrasound (34 – 37 weeks) significantly increased to 75.2% and 63.2% for the prediction of SGA and LGA, respectively[3]. Short-term outcomes of SGA and LGA fetuses are associated with cerebral palsy, hypoglycemia, hyperbilirubine-

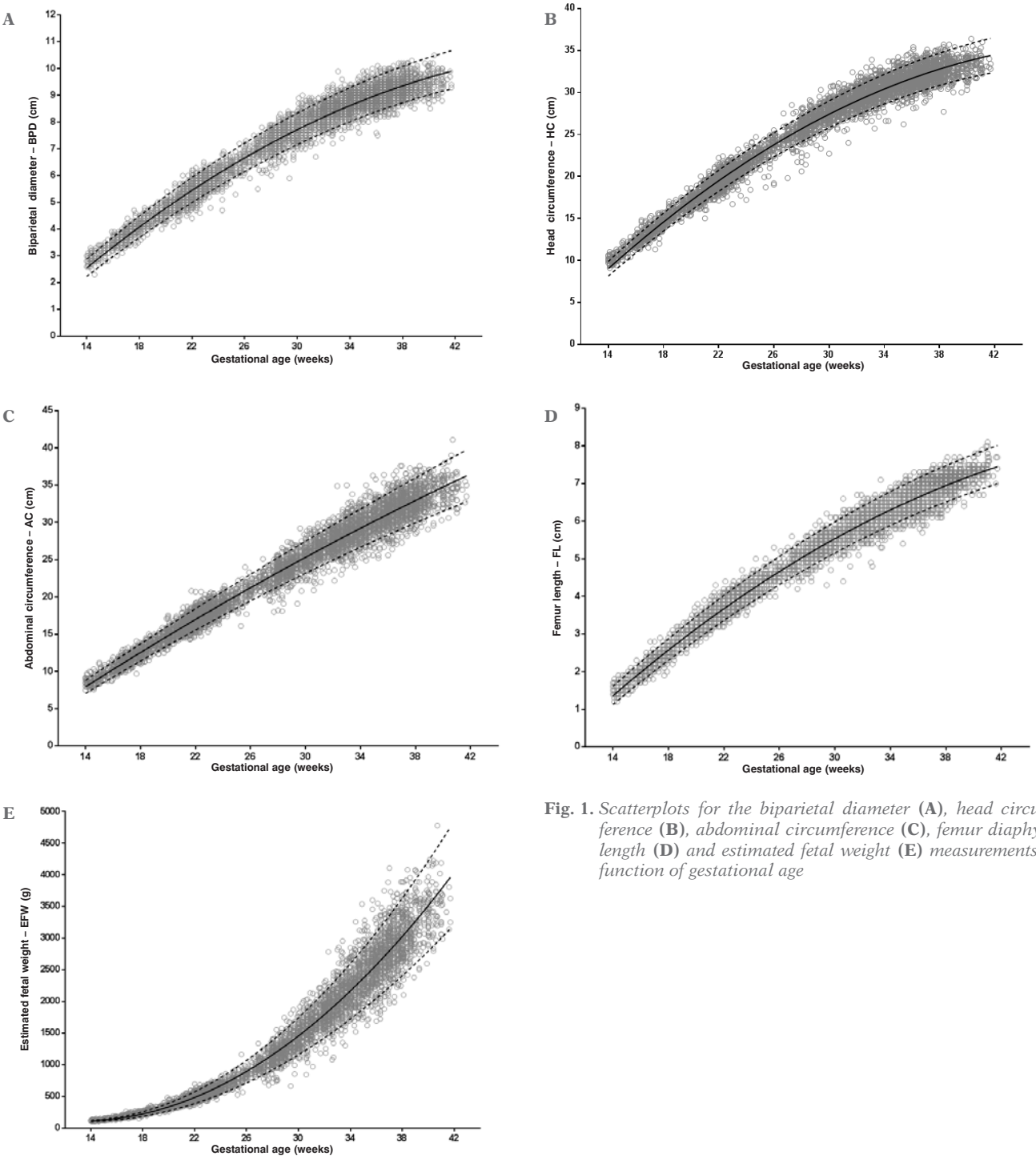

Fig. 1. *Scatterplots for the biparietal diameter* **(A)**, *head circumference* **(B)**, *abdominal circumference* **(C)**, *femur diaphysis length* **(D)** *and estimated fetal weight* **(E)** *measurements as function of gestational age*

GA	N	5th	50th	95th
14	81	2.2	2.6	2.9
15	64	2.6	3.0	3.3
16	151	3.0	3.3	3.7
17	191	3.3	3.7	4.1
18	138	3.7	4.1	4.5
19	101	4.0	4.4	4.9
20	207	4.4	4.8	5.2
21	441	4.7	5.1	5.6
22	680	5.0	5.5	5.9
23	306	5.3	5.8	6.3
24	132	5.6	6.1	6.6
25	81	5.9	6.4	6.9
26	63	6.2	6.7	7.2
27	109	6.4	7.0	7.5
28	272	6.7	7.2	7.8
29	173	6.9	7.5	8.1
30	211	7.2	7.7	8.3
31	197	7.4	8.0	8.6
32	322	7.6	8.2	8.8
33	286	7.8	8.4	9.1
34	225	8.0	8.7	9.3
35	271	8.2	8.9	9.5
36	305	8.4	9.0	9.7
37	297	8.6	9.2	9.9
38	192	8.7	9.4	10.1
39	75	8.9	9.6	10.3
40	64	9.0	9.7	10.4
41	21	9.2	9.9	10.6

GA – gestational age

Tab. 1. *Estimated 5th, 50th and 95th percentiles for the biparietal diameter measurement (cm) according to gestational age (weeks)*

GA	N	5th	50th	95th
14	81	8.1	9.0	9.9
15	64	9.5	10.5	11.4
16	151	10.9	11.9	12.8
17	191	12.2	13.2	14.3
18	138	13.5	14.6	15.6
19	101	14.7	15.9	17.0
20	207	15.9	17.1	18.3
21	441	17.1	18.3	19.5
22	680	18.2	19.5	20.7
23	306	19.3	20.6	21.9
24	132	20.4	21.7	23.0
25	81	21.4	22.7	24.1
26	63	22.3	23.8	25.2
27	109	23.2	24.7	26.2
28	272	24.1	25.7	27.2
29	173	25.0	26.5	28.1
30	211	25.8	27.4	29.0
31	197	26.6	28.2	29.8
32	322	27.3	29.0	30.7
33	286	28.0	29.7	31.4
34	225	28.6	30.4	32.2
35	271	29.2	31.0	32.8
36	305	29.8	31.7	33.5
37	297	30.3	32.2	34.1
38	192	30.8	32.8	34.7
39	75	31.3	33.2	35.2
40	64	31.7	33.7	35.7
41	21	32.1	34.1	36.2

GA – gestational age

Tab. 2. *Estimated 5th, 50th and 95th percentiles for the head circumference measurement (cm) according to gestational age (weeks)*

mia, polycythemia, or dystocia[4,5]. Long-term outcomes of these fetuses are associated with high risk of systemic arterial pressure, diabetes mellitus and coronary heart disease[6].

The ethnic factor shows to interfere in the fetal growth pattern, impossible that reference ranges of fetal biometric parameters from homogeneous population could be applied in other populations, mainly heterogeneous populations. In an American study with singleton pregnancies between 17 and 22.9 weeks, Afro-American fetuses have smaller abdominal circumference (AC) than Caucasian fetuses. As AC contributes heavily to the estimated fetal weight, the Afro-American fetuses could be mistakenly underestimated[7].

There are a lot of reference charts for fetal biometric parameters established for different populations, i.e. European, African, Asian and Latin American[8–14]. All these reference charts were unconditional (cross-sectional) studies, because they are more appropriate for the quantification of fetal size[15]. There is a unique unconditional study with 31,476 singleton Brazilian pregnant women which established reference charts for fetal biometric parameters[16]. However, because of a lot of miscegenation of Brazilian population with great ethnic differences among its regions, it is not possible to establish reference charts for fetal biometric parameters to the whole Brazilian population.

The objective of this study is to establish reference charts for fetal biometric parameters between 14 and 41 weeks of gestation in a non-selected risk population from Uberaba, Southeast of Brazil.

Materials and methods

We performed a retrospective cross-sectional study from February 2012 through March 2015 among pregnant women who underwent routine second and third ultrasound exams between 14 and 41 weeks of gestation. This study was approved by the Ethic Committee of Uberaba University (UNIUBE), the consent form which was not

GA	N	5th	50th	95th
14	81	7.1	7.9	8.8
15	64	8.2	9.1	10.1
16	151	9.3	10.3	11.3
17	191	10.3	11.4	12.5
18	138	11.4	12.6	13.7
19	101	12.5	13.7	14.9
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21	441	14.5	15.9	17.3
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34	225	26.7	29.2	31.8
35	271	27.5	30.2	32.9
36	305	28.4	31.1	33.9
37	297	29.2	32.1	35.0
38	192	30.0	33.0	36.0
39	75	30.8	33.9	37.0
40	64	31.5	34.8	38.0
41	21	32.3	35.7	39.0

GA: gestational age

Tab. 3. *Estimated 5th, 50th and 95th percentiles for the abdominal circumference measurement (cm) according to gestational age (weeks)*

GA	N	5th	50th	95th
14	81	1.1	1.4	1.6
15	64	1.4	1.7	1.9
16	151	1.7	2.0	2.3
17	191	2.0	2.3	2.6
18	138	2.3	2.6	2.9
19	101	2.6	2.9	3.2
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31	197	5.3	5.8	6.2
32	322	5.5	6.0	6.4
33	286	5.7	6.1	6.6
34	225	5.9	6.3	6.8
35	271	6.1	6.5	7.0
36	305	6.2	6.7	7.1
37	297	6.4	6.8	7.3
38	192	6.5	7.0	7.5
39	75	6.6	7.1	7.6
40	64	6.8	7.3	7.8
41	21	6.9	7.4	7.9

GA: gestational age

Tab. 4. *Estimated 5th, 50th and 95th percentiles for the femur diaphysis length measurement (cm) according to gestational age (weeks)*

necessary because it was a retrospective study. Low-risk pregnant women were selected randomly from public and private health services of the metropolitan region of Uberaba, Minas Gerais state, Southeast of Brazil.

The inclusion criteria were the following: singleton pregnancies, lack of bleeding in the first trimester, gestational age determined by the last menstrual period (LMP) and confirmed by first trimester ultrasound using crown-rump length (CRL) until 13th week, lack of fetal structural malformations or chromosomal abnormalities in the ultrasound exam. The exclusion criteria were maternal chronic diseases, such as arterial systemic hypertension, diabetes mellitus, systemic lupus erythematosus and renal diseases. Postnatal outcomes were not available. Each pregnant woman was examined only once and postnatal outcomes were not available.

The ultrasound exams were performed at the Mario Palmério University Hospital and Radiologic Clinic of Uberaba as routine visits in the second and third trimesters of pregnancy. These ultrasound exams were performed by only two examiners (ABP and TMRCC) with Fetal Medicine Foundation (FMF) accreditation. The ultrasound exams were performed transabdominally using only two apparatuses (Accuvix V20 – Samsung, Seoul, Korea) equipped with a convex head (3D4-6ET) and Voluson E6 – General Electric, Zipf, Austria) equipped with a convex head (RAB4-6L).

The following fetal biometric parameters were assessed: biparietal diameter (BPD), head circumference (HC), AC and femur diaphysis length (FDL), according to the guidelines proposed by the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG)[17]. The estimated fetal weight (EFW) was automatically calculated by the apparatus using the Hadlock formula [Log 10 birth weight = $1.4787 + 0.001837 \times (BPD)^2 + 0.0458 \times (AC) + 0.158 \times (FDL) - 0.003343 \times (AC \times FDL)$][18].

For the BPD measurement, a cross-sectional view of the fetal head was obtained at the level of thalamus, with symmetrical appearance of the hemispheres, continuous midline echo broken in the middle by the cavum septi pellucidi

GA	N	5th	50th	95th
14	81	104	115	125
15	64	113	129	142
16	151	130	151	170
17	191	155	183	209
18	138	186	225	260
19	101	226	276	322
20	207	273	336	395
21	441	328	406	479
22	680	390	485	575
23	306	459	573	682
24	132	537	671	800
25	81	621	779	930
26	63	714	895	1070
27	109	813	1021	1222
28	272	921	1157	1385
29	173	1036	1302	1559
30	211	1158	1456	1745
31	197	1288	1620	1942
32	322	1425	1793	2150
33	286	1571	1975	2369
34	225	1723	2167	2600
35	271	1883	2369	2842
36	305	2051	2579	3095
37	297	2226	2799	3359
38	192	2409	3029	3634
39	75	2599	3268	3921
40	64	2797	3516	4219
41	21	3002	3774	4528

GA: gestational age

Tab. 5. *Estimated 5th, 50th and 95th percentiles for the estimated fetal weight measurement (g) according to gestational age (weeks)*

and thalamus and no cerebellum visualized. The calipers are placed on the outer and inner edges of the skull. For the HC measurement, the ellipse was directly placed outside of the skull bone echoes. The HC was calculated by the following equation: HC = 1.62 × (BPD + occipital frontal diameter, OFD). For the AC measurement, a transverse cross-section of the abdomen was obtained, with the umbilical vein at the level of the portal sinus, stomach bubble visualized and kidneys not visible. The AC was obtained using the anteroposterior abdominal diameter (APAD) and transverse abdominal diameter (TAD). The APAD measurement was obtained placing the calipers on the outer borders of the body outline, from the posterior aspect to the anterior abdominal wall. The TAD measurement was obtained placing the calipers on the outer borders of the body outline, across the abdomen at the widest point. The AC was calculated by the following equation: AC = 1.57 × (APAD + TAD). To the FDL measurement, the longest axis of femur was obtained and each caliper was placed at the ends of the ossified diaphysis without including the distal femoral epiphysis, if visible[17].

The data were transferred to Excel spread sheet (Microsoft Corp., Redmond, WA, USA) and analyzed by one of the authors (WPM) using the PASW program (version 18.0, SPSS Inc., Chicago, IL, USA) and GraphPad (version 5.0, GraphPad Software, San Diego, CA, USA). Maternal characteristics such as age, height, weight, body mass index (BMI), number of pregnancies, parity and gestational age at ultrasound exam were characterized by mean ± standard deviation (*SD*). Cigarette smokers and alcohol consumers were characterized by percentage (%). The BPD, HC, AC, FDL and EFW measurements were expressed as mean, *SD* and maximum and minimum values. In order to obtain reference charts for BPD, HC, AC, FDL and EFW measurements as function of gestational age (GA), we have used a polynomial regression model, as recommended by Altman and Chitty[19]. Regression analysis has been used to obtain the best-fit model polynomial equation for the fetal biometric parameters measurements and their respective *SD* values depending on the gestational age. Percentiles of these measurements were calculated using the following formula: = mean + (*SD* × *K*), where *K* is the corresponding percentile of standard normal distribution. Percentiles 5th, 50th and 95th were determined for each gestational age[19].

Results

We assessed 5656 non-selected risk singleton pregnancies. The mean ± *SD* of age (years), weight (kg), height (cm), BMI (kg/m²), number of pregnancies, parity and gestational age at ultrasound exam (weeks) amounted to 29.4 ± 6.1, 71.6 ± 15.1, 162.5 ± 11.1, 27.0 ± 5.8, 1.8 ± 1.1, 0.6 ± 0.8 and 27.8 ± 7.0, respectively. According to ethnicity, 84.5% were white. Cigarette smokers and alcohol consumers represented 3.1% and 2.7%, respectively.

The mean, *SD*, minimum and maximum of BPD (cm), HC (cm), AC (cm), FDL (cm) and EFW (g) were 6.9 ± 1.9 (2.3 – 10.5), 24.51 ± 6.61 (9.1 – 36.4), 22.8 ± 7.3 (7.5 – 41.1), 4.9 ± 1.6 (1.2 – 8.1) and 1365 ± 1019 (103 – 4777), respectively. The second-degree polynomial regressions between the evaluated parameters and GA resulted in the following formulas: BPD = –4.044 + 0.540 × GA – 0.0049 × GA² (R^2 = 0.97); HC= –15.420 + 2.024 × GA – 0.0199 × GA² (R^2 = 0.98); AC = –9.579 + 1.329 × GA – 0.0055 × GA² (R^2 = 0.97); FDL = –3.778 + 0.416 × GA – 0.0035 × GA² (R^2 = 0.98) and EFW = 916 – 123 × GA + 4.70 × GA² (R^2 = 0.96); respectively.

Figure 1 shows the scatterplots for the BPD (A), HC (B), AC (C), FDL (D) and EFW (E) measurements (cm) as the function of GA (weeks). Tables 1, 2, 3, 4, 5 present the 5th, 50th and 95th percentiles for the BPD, HC, AC, FDL and EFW measurements between 14 and 41 weeks of gestation, respectively.

Discussion

In this study, we established reference charts for the fetal biometric parameters in a non-selected risk population from Uberaba, Southeast of Brazil. The effect of ethnic

Author	Country	Year	Gestational age interval (weeks)	Number of cases	BPD (cm)	AC (cm)	FDL (cm)	EFW (g)
Peixoto *et al.*	Brazil	2017	14 - 41	5656	6.9	22.8	4.9	1365
Araujo Júnior *et al.*[16]	Brazil	2014	18 - 38	31,476	6.9	23.4	5.1	1387.9
Kwon *et al.*[12]	Korea	2014	15 - 40	986	6.7	21.7	4.9	-
Tahmasebpour *et al.*[25]	Iran	2012	15 - 28	3,011	-	-	3.6	-
Briceño *et al.*[14]	Colombia	2013	12 - 40	792	6.3	21.3	4.6	-
Merialdi *et al.*[26]	Peru	2005	20 - 38	1,142	-	25.5	5.5	-
Barrios-Prieto *et al.*[13]	Mexico	2013	14 - 41	1,833	6.7	23.0	4.9	1464.0
Frančišković *et al.*[22]	Croatia	2011	22 - 41	2,178	7.9	26.9	5.8	-
Adiri *et al.*[10]	Nigeria	2015	13 - 40	460	6.8	-	4.9	-
de la Vega *et al.*[27]	Puerto Rican	2008	13 - 38	548	6.3	21.1	4.6	1150.5
Landis *et al.*[20]	Democratic Republic of Congo	2009	15 - 40	755	-	-	-	1364.5

Tab. 6. *Comparison of mean biparietal diameter (BPD), abdominal circumference (AC), femur diaphysis length (FDL) and estimated fetal weight (EFW) between our studies and other ones from different ethnic origin*

origin influences the fetal biometric parameters. Kwon *et al.*[12] comparing their fetal biometric parameters measurements with the North American and UK populations, Korean fetuses had greater BPD, head circumference (HC), and AC in the first half of pregnancy but tended to measure progressively smaller with advancing gestational age. In a conditional study which established reference charts between 15 and 40 weeks of gestation in a Congolese population, comparing with reference charts derived from developed populations consistently overestimated the 50th centile EFW value for Congolese fetuses by roughly 5–12%[20].

In this study, we proposed to assess reference charts for fetal biometric parameters in a specific population of a region of Brazil. According to the census of 2010, 43.1% of the Brazilian population is classified as mixed ethnic [21], constituting the largest miscegenation population in the world – as a result – the Brazilian population is classified due to skin color and not race. Furthermore, the rate of miscegenation changes in its different regions. Specifically in Uberaba city, Southeast of Brazil, in the same census of 2010, the rate of mixed amounted to 28.0%[21], in other words a difference of 35.1% regarding the whole Brazilian population. Because of regional ethnic differences among populations in the same country, some authors have established reference charts for fetal biometrical parameters to specific regions[14,22].

Araujo Júnior *et al.*[16] determined reference charts for fetal biometric parameters in 31,476 singleton Brazilian pregnant women. This study was carried out in the metropolitan region of Sao Paulo city, which also presents different rates of mixed population regarding the whole Brazilian population. Despite a large sample, the ultrasound exams were performed by several sonographers with different expertise in this method, and 12 different ultrasound apparatuses were used to perform the ultrasound exams and the gestational age interval included only 18 to 38 weeks of gestation. It is known that changing ultrasound settings or apparatus may affect the calculation and repeatability of measurement of fetal myocardial performance index [23], in the same way the professional experience in the fetal heart volume by a three-dimensional ultrasound[24]. In our study, all ultrasound exams were performed by only two experienced examiners with FMF accreditation, and the ultrasound exams were performed using only two apparatuses. Comparing our results with those of Araujo Júnior *et al.*[16] between 18 and 38 weeks of gestation, the means of BPD, AC, FDL and EFW were similar, showing that the ethical factor did not have a significant importance in this local sample of Brazilian population. However, new studies with larger samples including other Brazilian regions are necessary to prove the real influence of ethical effect on the fetal biometry.

Kwon *et al.*[12] established unconditional reference charts for fetal biometric parameters in 986 fetuses between 15 and 40 weeks of gestation. Comparing our results, we observed that the means of all biometric parameters were similar. Dubiel *et al.*[9] established reference charts for fetal biometric parameters of a Caucasian Polish population with 959 normal pregnant women between 20 and 40 weeks of gestation. Comparing the median of BPD, AC, FDL and EFW of our results with those of Dubiel *et al.*[9], we observed that they were similar. Table 6 shows the comparison of mean BPD, AC, FDL and EFW of our study with other ones from different ethnic populations.

As a summary, we established reference charts for the fetal biometric parameters in a non-selected risk population from Uberaba, Southeast of Brazil. As we did not observe significant differences between the fetal biometric parameter measurement obtained in our study and the ones from Araujo Júnior *et al.*[16], who assessed a larger Brazilian population sample, we believe that our sample can represent a great miscegenation of the Brazilian population. These reference charts may be used in Brazilian pregnant women with high-risk of intrauterine growth disorders.

Conflict of interest

Authors do not report any financial or personal links with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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