Chapter

Assessment of Fetal Gestational Age in the First Trimester in Normal and Abnormal Pregnancies: Which Sonographic Parameter to Use?

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Abstract

To compare the correlation of various fetal ultrasound parameters to foot length, crown-rump length, and gestational age by date to determine the best estimate at 10–14 completed weeks' gestation and to provide ratios of fetal parameters for assessment of fetal abnormalities in the first trimester. 35 routine obstetric scans were performed at 10–14 completed weeks' gestation for fetal parameters and ratios. The fetal crown-rump length (CRL), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) showed a linear correlation with the estimated gestational age by date (GA), crown-rump length (CRL), and foot length (FT) ($p < 0.001$), with the least correlation observed with GA and highest with FT. A combination of BPD, HC, AC, and FL correlated best with FT and then CRL and GA ($R^2 = 0.881$, 0.795, and 0.685, respectively, $p < 0.001$). With the addition of CRL, R^2 was 0.859. The ratio of FL/AC and FL/FT to FT, CRL, GA, BPD, and HC increases in an inverse relationship at 10–14 completed weeks' gestation. The combination of BPD, HC, AC, and FL provides a better estimation of gestational age than (and hence may replace) CRL or GA at 10–14 weeks' gestation.

Keywords: ultrasonography, fetus, pregnancy, first trimester, prenatal diagnosis

1. Introduction

The fetal foot is one of the first structures identifiable early in the human embryos. At the end of the fourth week of embryonic development, the limb buds appear as outpouchings from the ventrolateral body wall. At 6 weeks, the terminal portion of the limb buds flattens to form the hand- and footplates and becomes separated from the proximal segment by a circular constriction. It is known that the development of the lower limbs is similar to the upper limbs and lags by only 1–2 days. By 8 weeks (or 56 days), the digital separation is already complete. The fingers and the toes are distinct and separated in the hands and feet [1, 2]. In another word, the fetal hands and feet would be recognizable as distinct formed structures by 8 weeks of embryological development or 10 weeks by the last menstrual period (LMP) according to a 28 day cycle.

About a century ago, Streeter reported a linear correlation between gestational age and foot length in 704 human fetal specimens from around 50 days post-conception until birth [3]. This linear correlation has been confirmed by studies on live fetuses in utero on transabdominal [4–6] or transvaginal scans [7] or on dead fetuses at abortion [8–10] or stillbirth [11, 12], and nomograms have been developed for assessment of fetal gestational age with foot length (FT) from the first trimester to later gestation. Hence, fetal foot length could by itself stand as a proxy for gestational age even in early pregnancy.

Conventionally, crown-rump length (CRL) is used as the reference parameter for assessment of fetal gestational age in the first trimester ultrasound scan [13, 14]. It has been suggested that the ultrasound measurement of the crown-rump length in the embryo or fetus is the most accurate method to establish or confirm gestational age in the first trimester up to 13 + 6 weeks [14]. The use of routine first trimester ultrasound scan has been shown to be associated with a reduction in induction of labor for post-term pregnancy [15]. However, there is little information on the comparison of other fetal parameters including biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), and foot length to CRL in the assessment of gestational age in early gestation [16]. This information may be important for the assessment of fetal gestational age in the first trimester and subsequent management of pregnancy.

In order to ascertain the performance of various parameters in assessment of gestational age in the first trimester, in this chapter, the correlation between FT, CRL, and gestational age assessed by date (GA) will be compared from 10 to 14 weeks gestation. The correlation of the other fetal parameters (BPD, HC, AC, and FL) will also be compared to GA, CRL, and FT. Moreover, the ratio of some of these parameters will also be calculated and presented, as the availability of such ratios may be helpful when fetal abnormality is suspected on ultrasound examination in early pregnancy [17–19].

2. Method and material

Transabdominal ultrasound examination was performed as a part of routine antenatal assessment for women attending an obstetric clinic at a gestation of 10–14 + 6 weeks from March 7, 2014, to September 7, 2016 (Accuvix V20 Prestige, Medison with 4–8 MHz volumetric transducer or EPIQ 7, Philips with X6–1 matrix transducer). The following fetal measurements were taken prospectively: crown-rump length (CRL), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), and foot length (FT). Only pregnancies with normal outcomes were included in the analysis and excluded if the entire foot could not be clearly seen during the ultrasound examination. The fetal foot length was measured from the most posterior point of the foot in its long axis to the tip of the first or the second toe whichever was longer (**Figure 1**). The estimated gestational age in weeks (GA) was calculated either from the last normal menstrual period (LMP) or from the first trimester dating scan if there was a discrepancy of more than a week [14]. This was a retrospective analysis involving minimal risk, conforming to the standards established by the NHMRC not requiring ethical review; ethics approval was therefore not sought within the institution [20].

Results for 35 ultrasound scans were analyzed with SPSS statistical package version 20 (SPSS Inc., Chicago, IL, USA). A two-sided probability (p) value of <0.05 was considered statistically significant. The regression models for the fetal measurements were obtained and would be presented in the relevant sections.

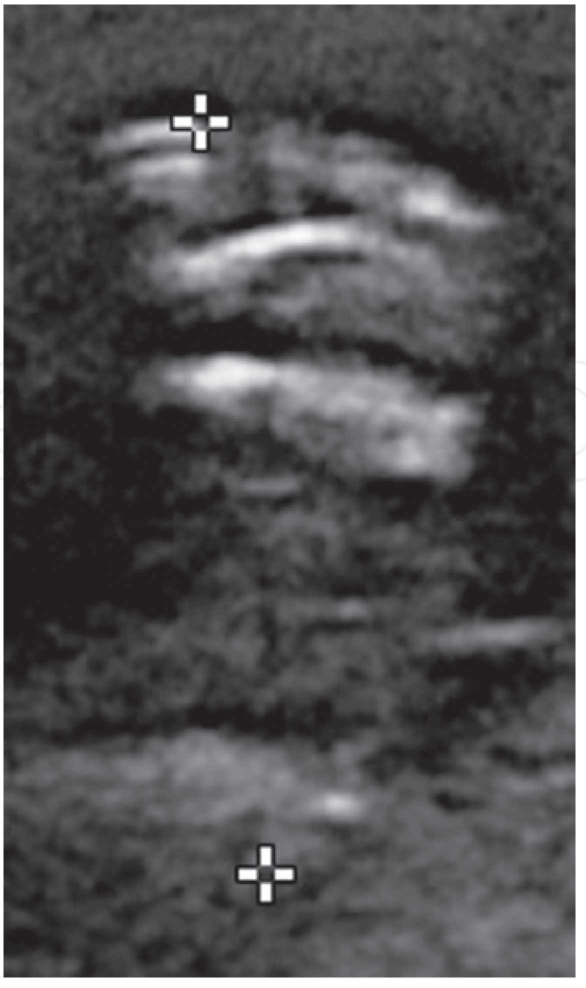

Figure 1.
Fetal foot on first trimester ultrasound scan.

3. Results

3.1 Demographic characteristics

The mean age, gravidity, and parity were 32.0 years, 2.3, and 0.7, respectively (**Table 1**). A total of 32 out of the 35 women were Asians (91.4%) and 3 were Caucasians (8.6%).

3.2 Comparison of the correlation between FT, CRL, and GA

The correlation of foot length, crown-rump length, and the gestational age assessed by date are shown in **Figures 2–4** and tabulated in **Table 2**. FT, CRL, and GA all showed positive correlation with one another in a linear fashion ($p < 0.001$)

	Mean ± S.D.	Range
Age (years)	32.0 ± 4.6	21–44
Gravidity	2.3 ± 1.5	1–8
Parity	0.7 ± 0.7	0–3

SD, standard deviation.

Table 1.
The demographic date of the pregnant women included in the study.

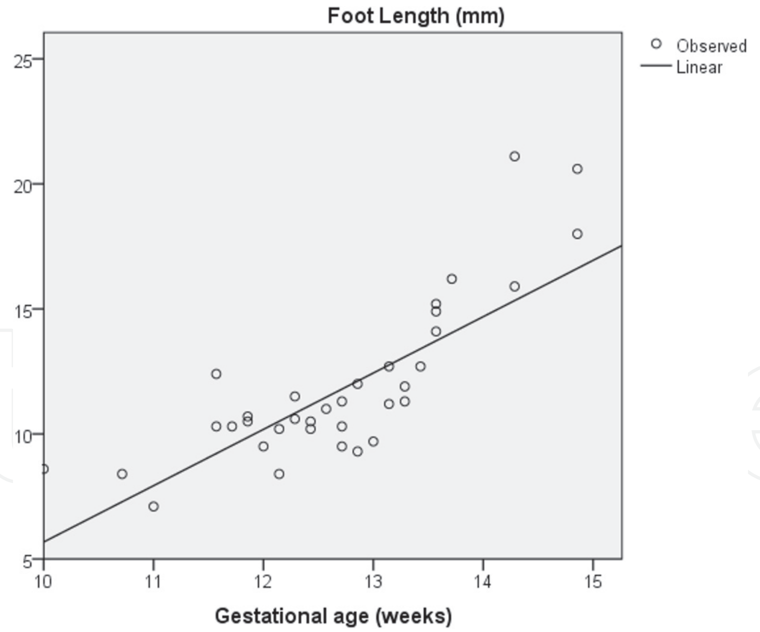

Figure 2.
The graph of fetal foot length against gestational age assessed by date. FT = GA × 2.472−19.44. R^2 = 0.675, p < 0.001. FT, foot length (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

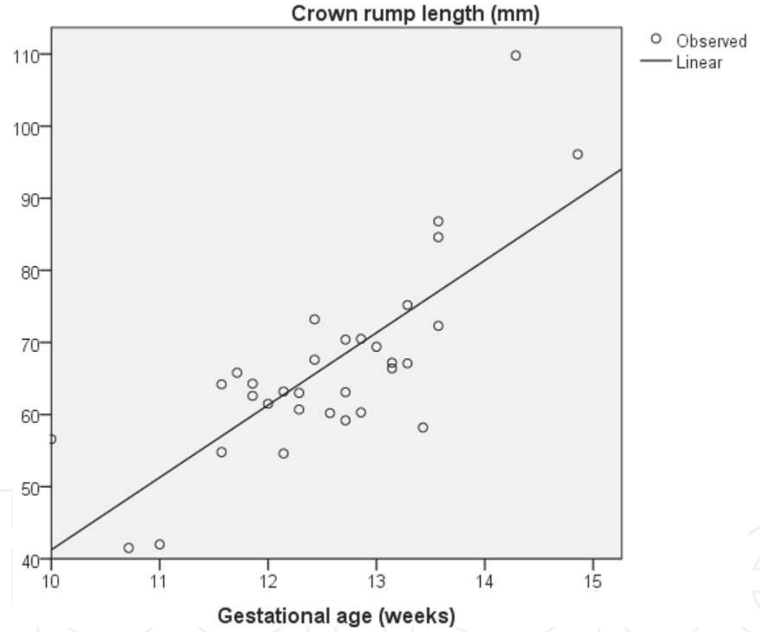

Figure 3.
The graph of fetal crown-rump length against gestational age assessed by date. CRL = GA × 10.464−64.682. R^2 = 0.608, p < 0.001. CRL, crown-rump length (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

(**Figures 2**–**4**). The coefficient of determination of regression (R^2) was the highest between FT and CRL (0.804), lower between FL and GA (0.675), and the lowest between CRL and GA (0.608) (**Table 2**).

3.3 Comparison of the correlation of BPD, HC, AC, and FL to FT, CRL, and GA

The correlation of BPD, HC, AC, and FL with FT, CRL, and GA is shown in **Figures 5**–**7**, **8**–**10**, **11**–**13**, and **14**–**16**, respectively, and summarized in **Table 3**. Correlation in a linear fashion is seen for all ($p < 0.001$). Overall, the correlation

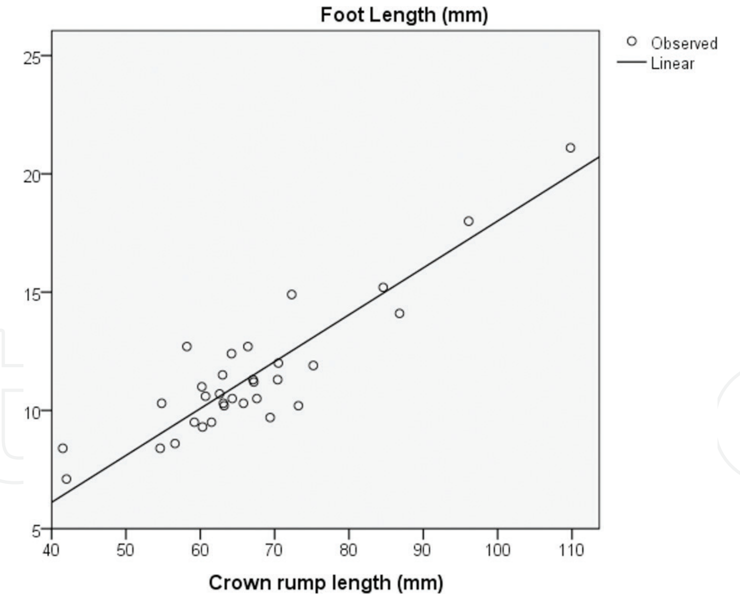

Figure 4.
The graph of fetal foot length against crown-rump length. FT = CRL × 0.187−1.074. R^2 = 0.804, p < 0.001. FT, foot length (mm); CRL, crown-rump length (mm); R^2, coefficient of determination of regression; p, probability.

Parameters	FT		CRL		GA	
	R^2	$p^†$	R^2	$p^†$	R^2	$p^†$
FT	–	–	0.804	<0.001*	0.675	<0.001*
CRL	0.804	<0.001*	–	–	0.608	<0.001*
GA	0.675	<0.001*	0.608	<0.001*	–	–

*FT, foot length (mm); CRL, crown rump length (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of linear regression; p, probability; †, ANOVA; *, statistically significant.*

Table 2.
The correlation between fetal foot length, crown-rump length, and gestational age assessed by date.

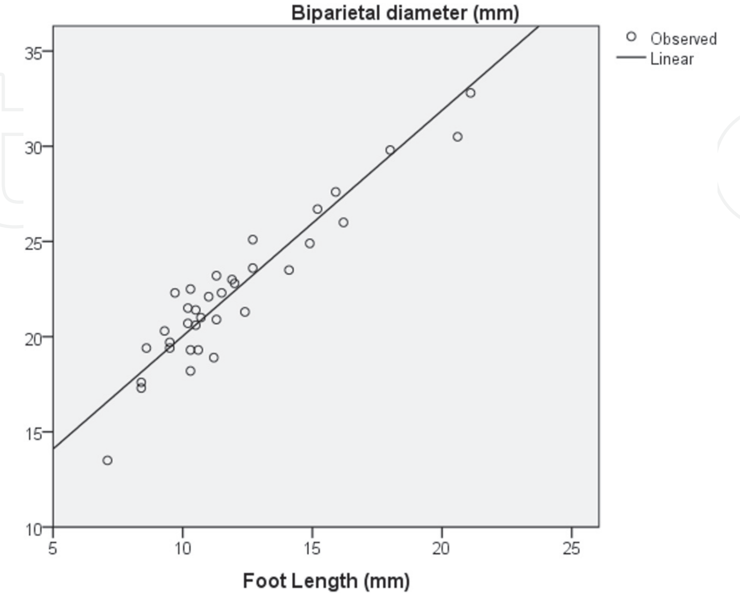

Figure 5.
The correlation of fetal biparietal diameter with foot length. BPD = FT × 1.131 + 8.748. R^2 = 0.884, p < 0.001. BPD, biparietal diameter (mm); FT, foot length (mm); R^2, coefficient of determination of regression; p, probability.

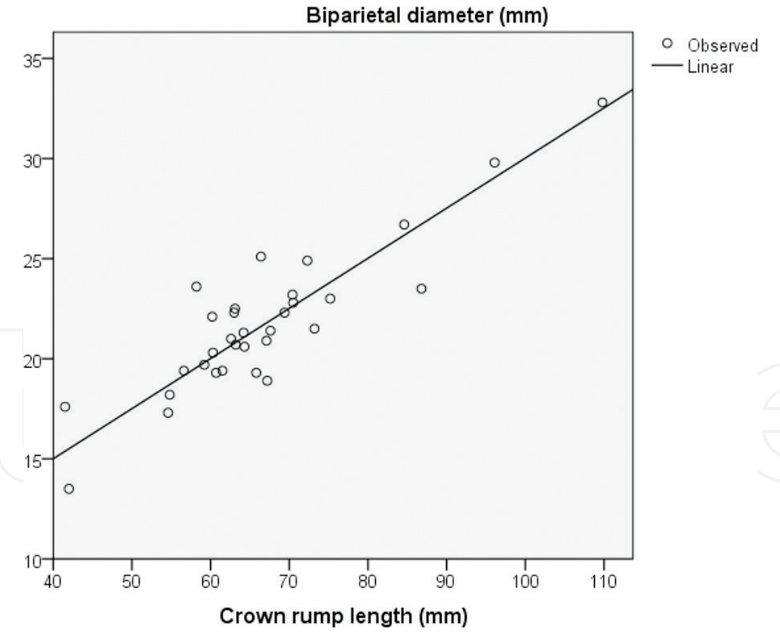

Figure 6.
The correlation of fetal biparietal diameter with crown-rump length. BPD = CRL × 0.239 + 5.78. R^2 = 0.793, $p < 0.001$. BPD, biparietal diameter (mm); CRL, crown-rump length (mm); R^2, coefficient of determination of regression; p, probability.

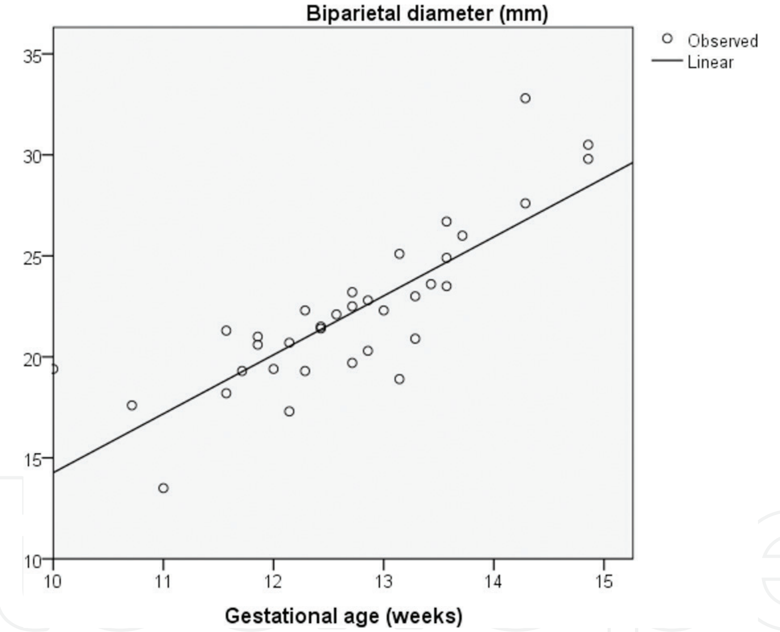

Figure 7.
The correlation of fetal biparietal diameter with gestational age assessed by date. BPD = GA × 3.01−15.967. R^2 = 0.693, $p < 0.001$. BPD, biparietal diameter (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

of BPD, HC, AC, and FL with FT was the highest, lower with CRL, and the lowest with GA (**Table 3**).

3.4 Comparison of combination of fetal parameters

The correlation of combinations of fetal parameters to FT, CRL, and GA is shown in **Table 4**. The highest correlation was seen between the combination of [BPD, HC, AC, and FL] and FT (R^2 = 0.881, p < 0.001), followed by correlation to CRL (R^2 = 0.795, p < 0.001), and the least with GA (R^2 = 0.685, p < 0.001). The addition of CRL to the combination yielded a lower R^2 value of 0.859. However, the correlation of the combination, with or without FT, to CRL yielded the same R^2 of 0.795 (p < 0.001).

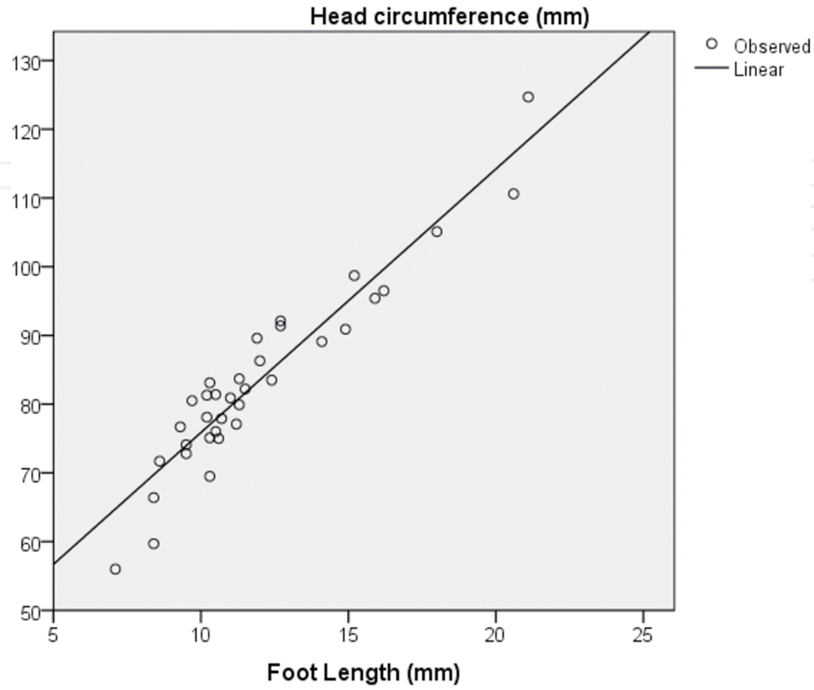

Figure 8.
The correlation of fetal head circumference with foot length. HC = FT × 3.932 + 36.257. R^2 = 0.897, p < 0.001. HC, head circumference (mm); FT, foot length (mm); R^2, coefficient of determination of regression; p, probability.

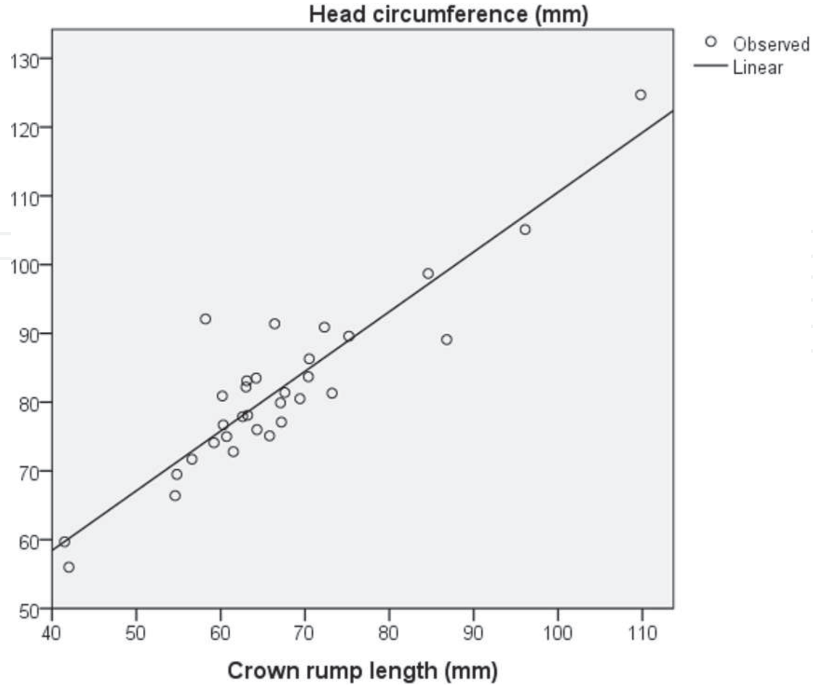

Figure 9.
The correlation of fetal head circumference with crown-rump length. HC = CRL × 0.869 + 23.646. R^2 = 0.834, p < 0.001. BPD, biparietal diameter (mm); CRL, crown-rump length (mm); R^2, coefficient of determination of regression; p, probability.

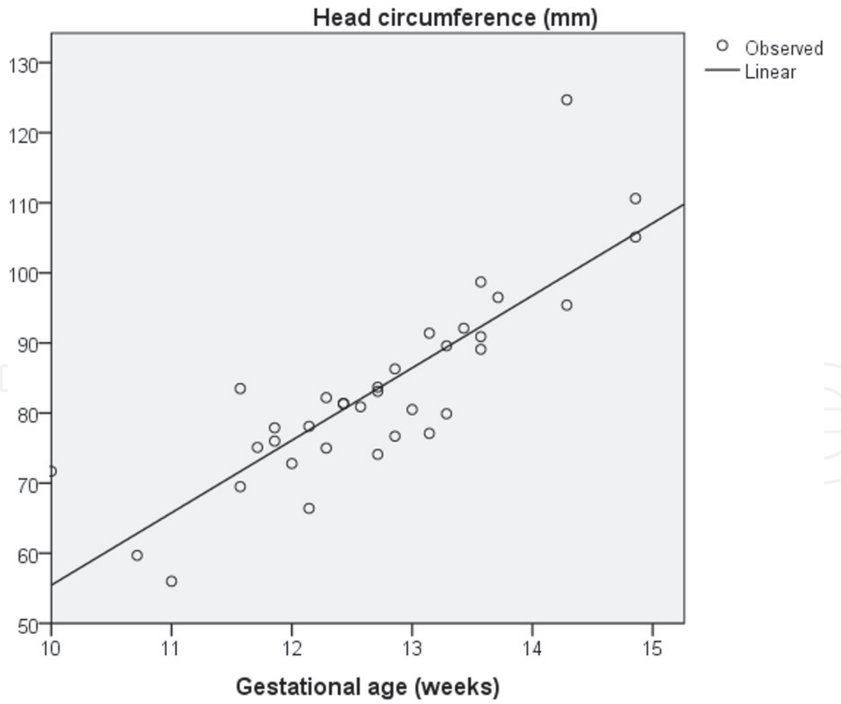

Figure 10.
The correlation of fetal head circumference with gestational age assessed by date. HC = GA × 10.488−49.951. R^2 = 0.706, p < 0.001. HC, head circumference (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

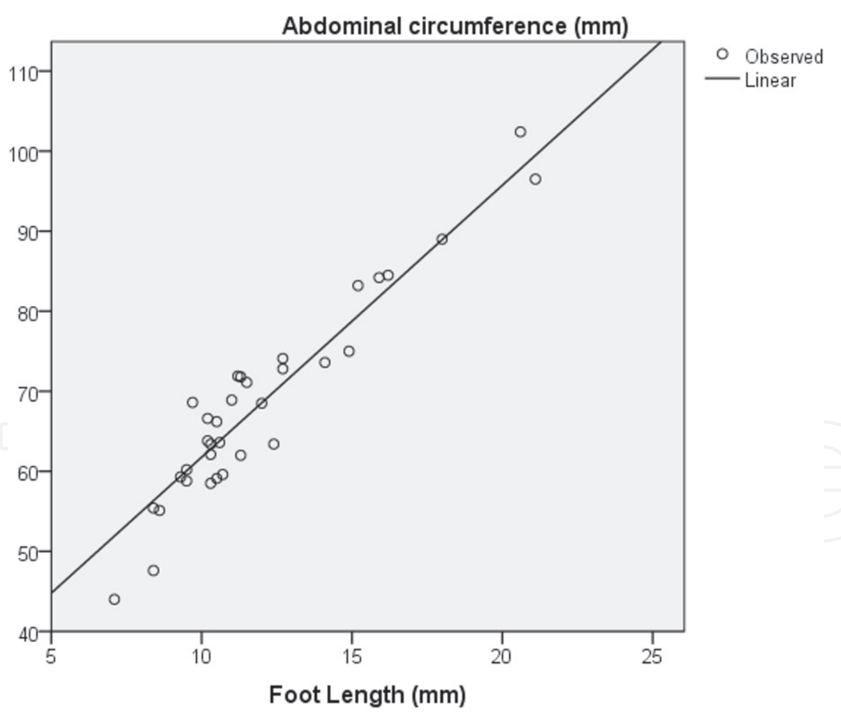

Figure 11.
The correlation of fetal abdominal circumference with foot length. AC = FT × 3.639 + 24.905. R^2 = 0.903, p < 0.001. HC, head circumference (mm); FT, foot length (mm); R^2, coefficient of determination of regression; p, probability.

The combination, in comparison to FT or CRL alone, gave a higher correlation to GA (compare to **Table 2**). However, the correlation of the combination of [BPD, HC, AC, and FL] or FT alone to CRL yielded a similar R^2 (0.795 vs. 0.804, compare **Table 4** to **Table 2**).

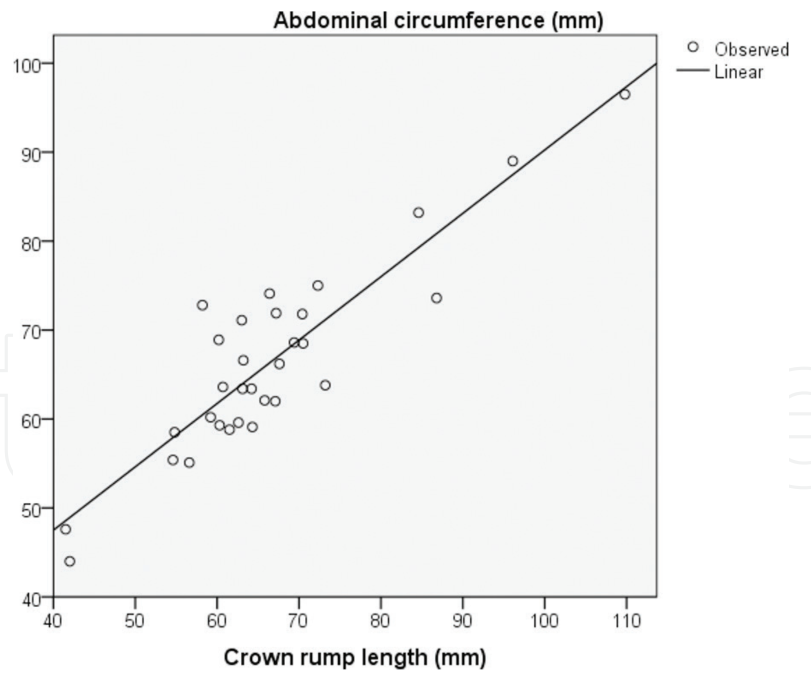

Figure 12.
The correlation of fetal abdominal circumference with crown-rump length. AC = CRL × 0.717 + 18.686. R^2 = 0.811, p < 0.001. AC, abdominal circumference (mm); CRL, crown-rump length (mm); R^2, coefficient of determination of regression; p, probability.

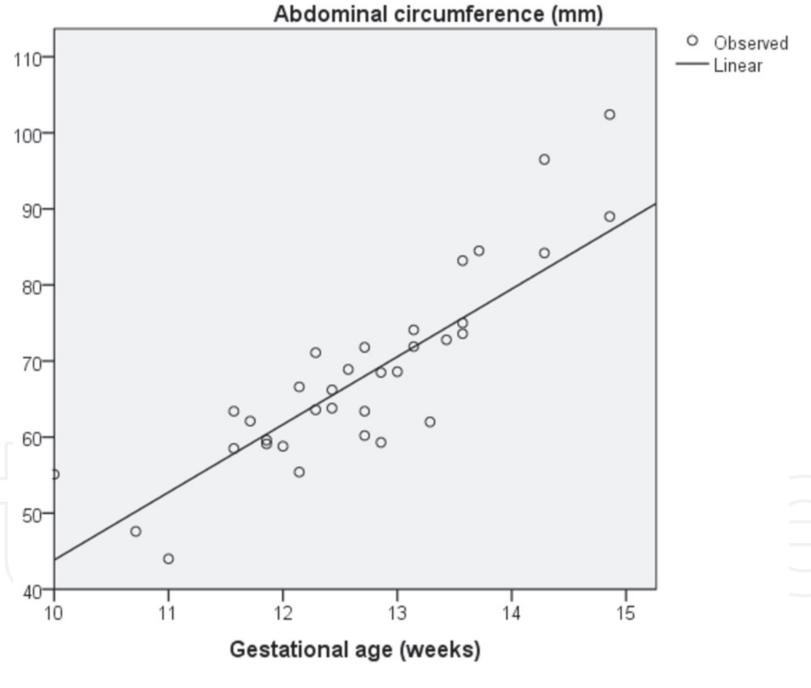

Figure 13.
The correlation of fetal abdominal circumference with gestational age assessed by date. AC = GA × 10.16–60.453. R^2 = 0.772, p < 0.001. AC, abdominal circumference (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

3.5 Ratios of fetal parameters

The ratios of fetal parameters FL/FT and FL/AC to FT, CRL, GA, BPD, and HC are shown in **Figures 17–21** and **22–26**, respectively. The correlation followed an inverse relationship, and the R^2 was higher with HC or BPD or CRL or FT than GA in general (**Table 5**).

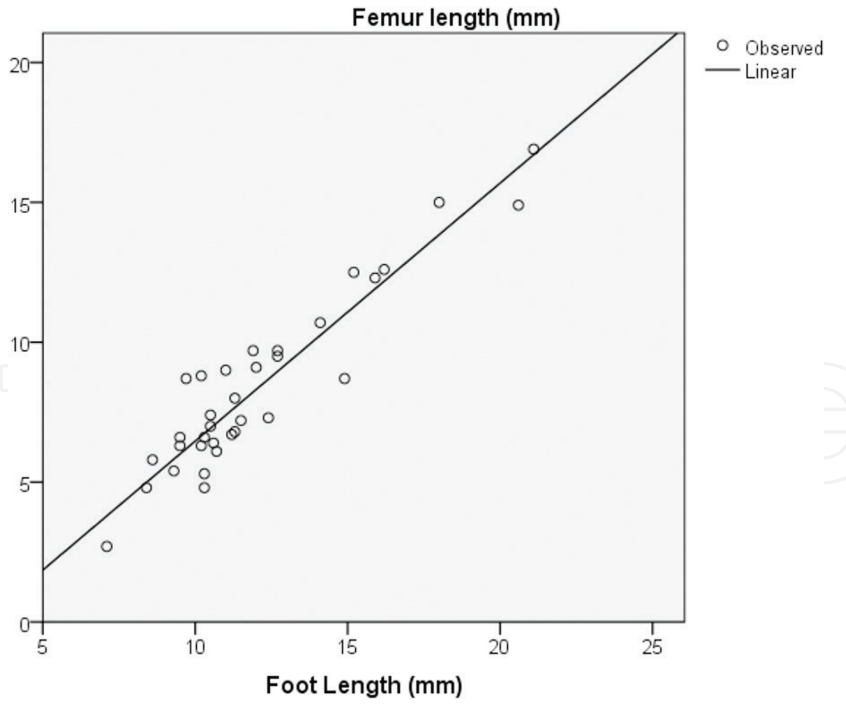

Figure 14.
The correlation of fetal femur length with foot length. FL = FT × 0.922−2.707. R^2 = 0.878, p < 0.001. FL, femur length (mm); FT, foot length (mm); R^2, coefficient of determination of regression; p, probability.

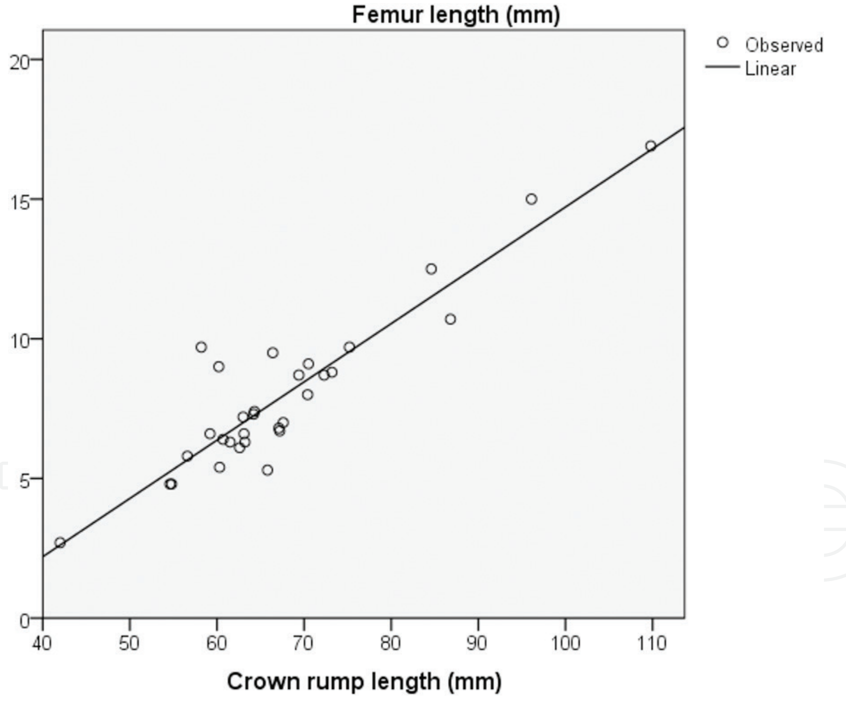

Figure 15.
The correlation of fetal femur length with crown-rump length. FL = CRL × 0.209−6.159. R^2 = 0.843, p < 0.001. FL, femur length (mm); CRL, crown-rump length (mm); R^2, coefficient of determination of regression; p, probability.

3.6 Intra- and inter-observer correlation

The Pearson coefficient for intra-observer correlation was 0.992 (p < 0.001) and for inter-observer correlation was 0.990 (p < 0.001) in the measurement of fetal foot length.

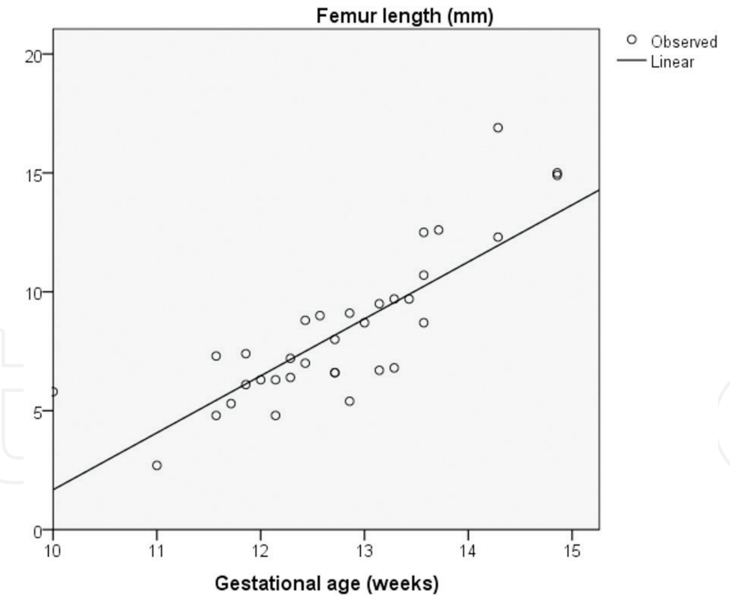

Figure 16.
The correlation of fetal femur length with gestational age assessed by date. FL = GA × 2.56−24.255. R^2 = 0.698, p < 0.001. FL, femur length (mm); GA, gestational age assessed by date (weeks); R^2, coefficient of determination of regression; p, probability.

	FT		CRL		GA	
	R^2	p†	R^2	p†	R^2	p†
BPD	0.884	<0.001*	0.793	<0.001*	0.693	<0.001*
HC	0.897	<0.001*	0.834	<0.001*	0.706	<0.001*
AC	0.903	<0.001*	0.811	<0.001*	0.772	<0.001*
FL	0.878	<0.001*	0.843	<0.001*	0.698	<0.001*
FT	–	–	0.804	<0.001*	0.675	<0.001*
CRL	0.804	<0.001*	–	–	0.608	<0.001*

*FT, foot length (mm); CRL, crown rump length (mm); GA, gestational age assessed by date (weeks); BPD, biparietal diameter (mm), HC, head circumference (mm); AC, abdominal circumference; FL, femur length (mm); R^2, coefficient of determination of regression; p, probability; †, ANOVA; *, statistically significant.*

Table 3.
The correlation of fetal biparietal diameter, head circumference, abdominal circumference, and femur length to foot length, crown-rump length, and gestational age assessed by date.

	FT		CRL		GA	
	R^2	p†	R^2	p†	R^2	p†
BPD, HC, AC, FL, FT, CRL	–	–	–	–	0.560	<0.001*
BPD, HC, AC, FL, CRL	0.859	<0.001*	–	–	0.601	<0.001*
BPD, HC, AC, FL, FT	–	–	0.795	<0.001*	0.685	<0.001*
BPD, HC, AC, FL	0.881	<0.001*	0.795	<0.001*	0.685	<0.001*

*BPD, biparietal diameter (mm); HC, head circumference (mm); AC, abdominal circumference (mm); FL, femur length (mm): FT, fetal foot length (mm); CRL, crown rump length (mm); R^2, coefficient of correlation of regression; p, probability; †, ANOVA; *, statistically significant.*

Table 4.
The correlation of multiple fetal parameters to foot length, crown-rump length, and gestational age.

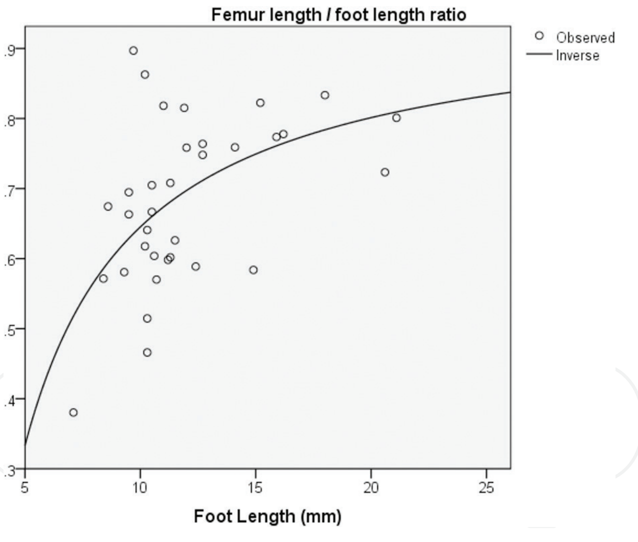

Figure 17.
The correlation of fetal femur length/foot length ratio to foot length. R^2 = 0.283, *p* = 0.001. R^2, *coefficient of determination of regression; p, probability.*

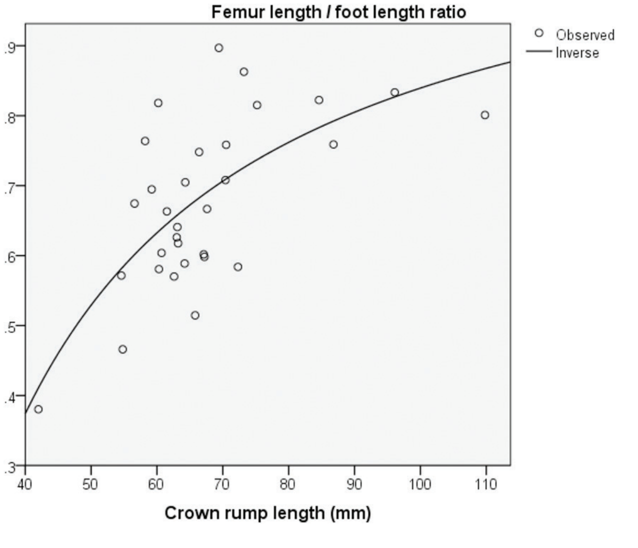

Figure 18.
The correlation of fetal femur length/foot length ratio to crown-rump length. R^2 = 0.458, *p* < 0.001. R^2, *coefficient of determination of regression; p, probability.*

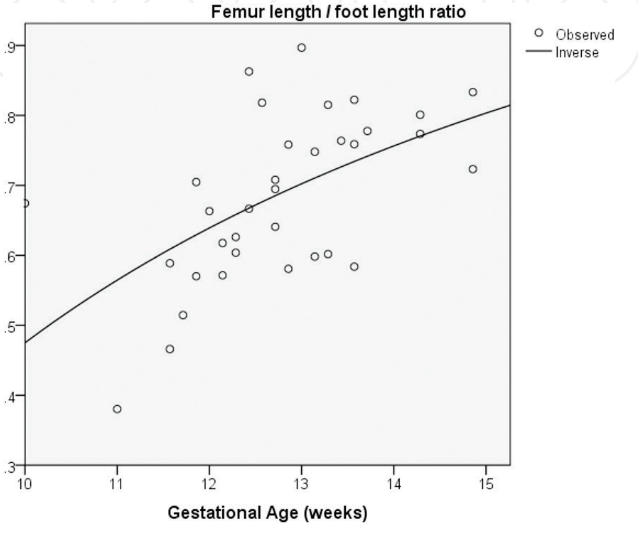

Figure 19.
The correlation of fetal femur length/foot length ratio to gestational age assessed by date. R^2 = 0.309, *p* = 0.001. R^2, *coefficient of determination of regression; p, probability.*

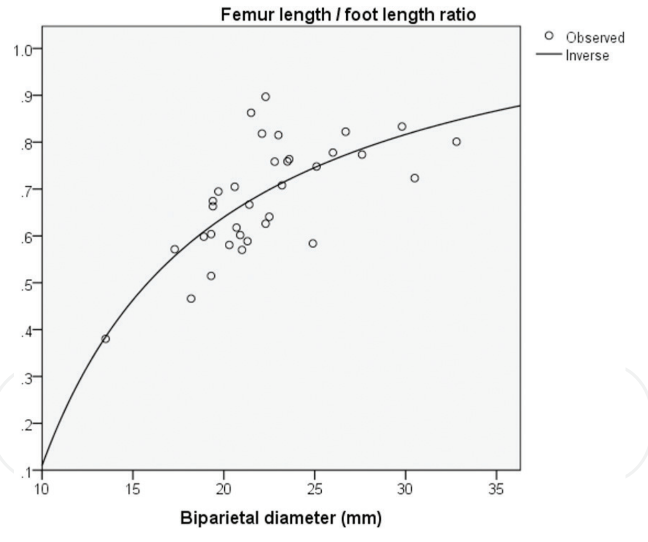

Figure 20.
The correlation of fetal femur length/foot length ratio to biparietal diameter. R^2 = 0.522, $p < 0.001$. *R^2, coefficient of determination of regression; p, probability.*

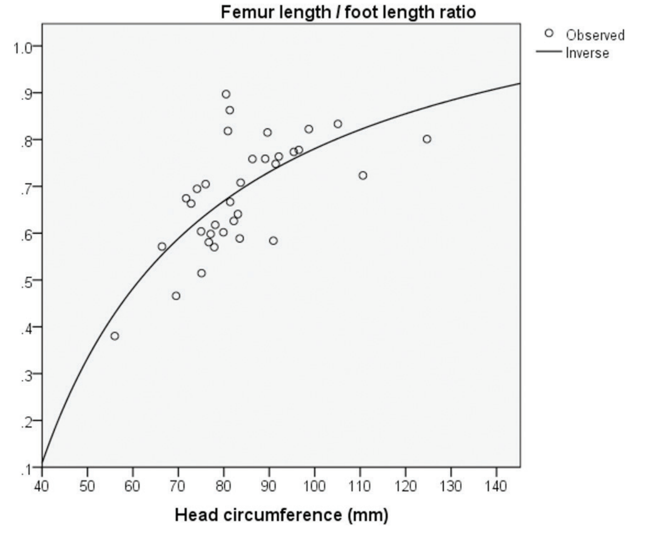

Figure 21.
The correlation of fetal femur length/foot length ratio to head circumference. R^2 = 0.477, $p < 0.001$. *R^2, coefficient of determination of regression; p, probability.*

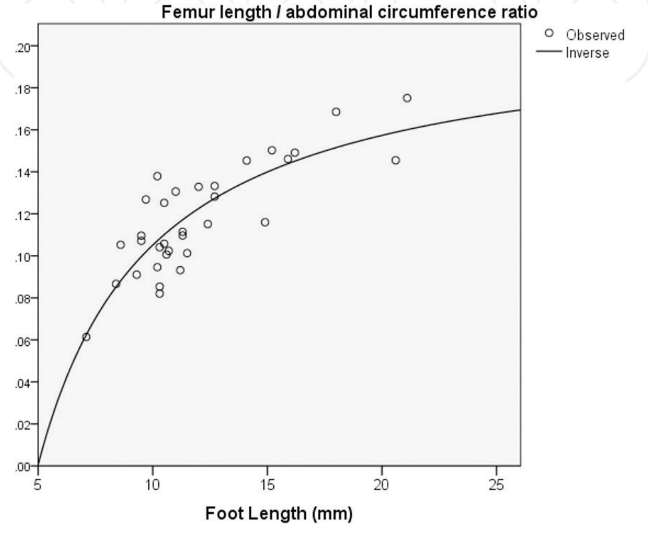

Figure 22.
The correlation of fetal femur length/abdominal circumference ratio to foot length. R^2 = 0.684, $p < 0.001$. *R^2, coefficient of determination of regression; p, probability.*

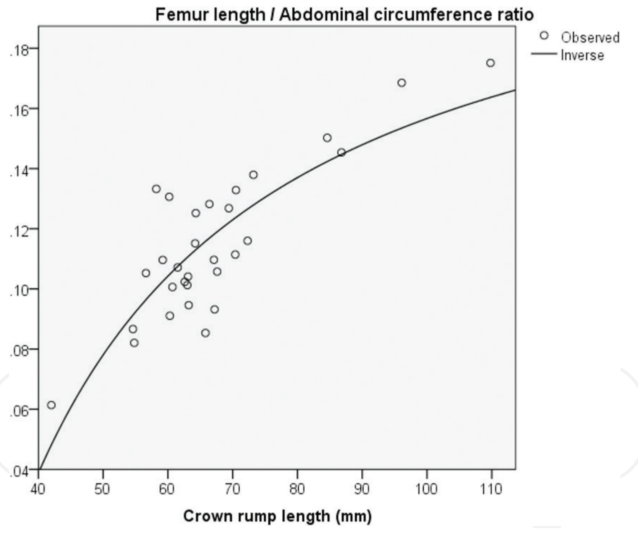

Figure 23.
The correlation of fetal femur length/abdominal circumference ratio to crown-rump length. $R^2 = 0.686$, $p < 0.001$. R^2, *coefficient of determination of regression; p, probability.*

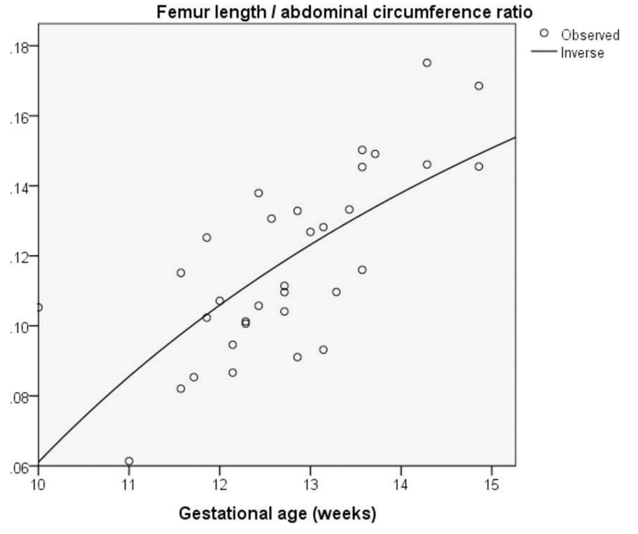

Figure 24.
The correlation of fetal femur length/abdominal circumference ratio to gestational age assessed by date. $R^2 = 0.495$, $p < 0.001$. R^2, *coefficient of determination of regression; p, probability.*

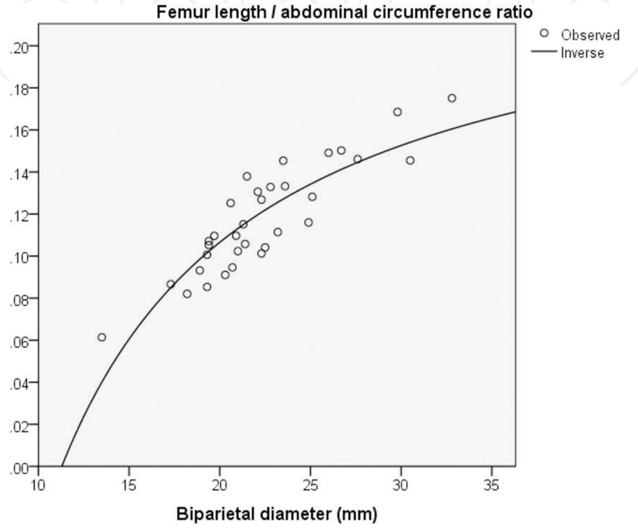

Figure 25.
The correlation of fetal femur length/abdominal circumference ratio to biparietal diameter. $R^2 = 0.765$, $p < 0.001$. R^2, *coefficient of determination of regression; p, probability.*

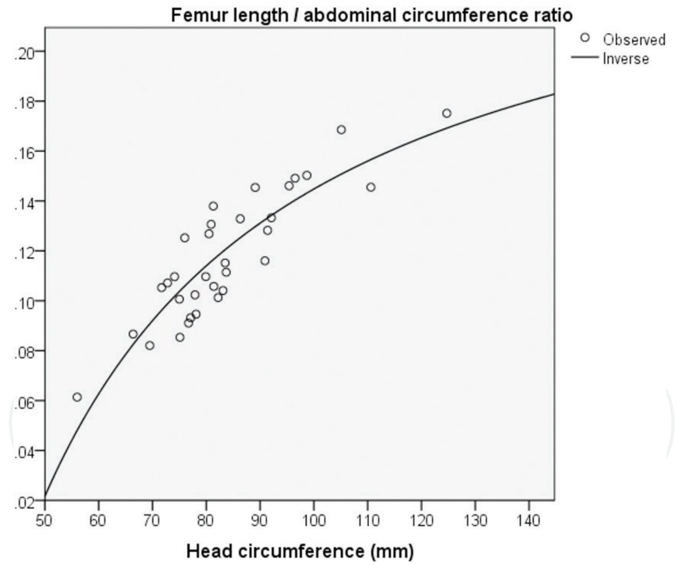

Figure 26.
The correlation of fetal femur length/abdominal circumference ratio to head circumference. R^2 = 0.773, p < 0.001. R^2, coefficient of determination of regression; p, probability.

	FL/AC		FL/FT	
	R^2	$p^†$	R^2	$p^†$
FT	0.684	<0.001*	0.283	0.001*
CRL	0.686	<0.001*	0.458	<0.001*
GA	0.495	<0.001*	0.309	0.001*
BPD	0.765	<0.001*	0.522	<0.001*
HC	0.773	<0.001*	0.477	<0.001*

*FL, femur length (mm); AC, abdominal circumference (mm); FT, foot length (mm); CRL, crown rump length (mm); GA, gestational age assessed by date (weeks); BPD, biparietal diameter (mm); HC, head circumference (mm); R^2, coefficient of determination of regression; p, probability; †, ANOVA; *, statistically significant.*

Table 5.
The correlation of foot length/abdominal circumference ratio to foot length, crown-rump length, and gestational age assessed by date, biparietal diameter, and abdominal circumference in a reverse relationship.

4. Discussion

An accurate estimation of fetal gestational age in early pregnancy is important for the assessment of the due date [14, 15] and fetal growth [21], the assignment of risk scores for the pregnancy [22], the prediction of fetal abnormality [23], and in the management of twin pregnancies [24]. CRL has been recommended as the standard parameter for assessment of fetal gestational age in the first trimester [14]. It was deduced that CRL gave a better estimation of fetal gestational age than the dates by the observation that it gave a better estimation of the date of delivery [14]. However, it is known that the measurement of CRL could be affected by the fetal posture. Variations in the estimation of fetal gestational age by a few days could be observed for the same gestation with different reference charts derived for CRL [4, 13, 25–28]. Since fetal foot length has been established as an accurate estimate for gestational age [3], it could be used as a proxy for the later. In this study, it could be seen that CRL correlates better with FT than GA. It can therefore be concluded that CRL is a better estimate of fetal gestational age than the date (**Table 2**), consistent with the previous observations [15]. However, in comparison to FT in the correlation to the other fetal parameters such as BPD, HC, AC, and FL, CRL performs less well in this study. The addition of CRL to the combination also lowers the R^2 (**Table 4**). Therefore, the use of the combination of BPD, HC, AC, and FL could well be applied from 10 to beyond 14 weeks for the estimation of fetal gestational age rather than using CRL below 14 weeks and the combination of BPD, HC, AC, and FL thereafter as in the current obstetrical practice [14]. Similarly when we use ratio of fetal parameters in the assessment of suspected fetal abnormalities, it may be better to use the ratio against fetal parameters such as FT, BPD, HC, or even CRL than against the gestational age by date, as long as the particular reference fetal parameter being used is not significantly affected by the abnormality in question (**Table 5**) [23, 29]. Of note, these ratios may not follow a linear correlation but rather an inverse relationship and vary according to the gestational age in the first trimester as alluded in a previous publication (**Figures 17–21, 22–26**, **Table 5**) [19].

The major limitation of the study is the sample size. The population studied comprised mainly of Asians, and hence there could be a question on generalizability. However, it has already been shown that ethnicity of the population is not an issue in sonographic estimation of fetal gestational age using crown-rump length [26]. Moreover, it has also been shown that less than 3.5% of the total variability of fetal skeletal growth was due to differences between populations when the mothers were adequately nourished [30].

With the advancement of ultrasound technology, small structures could be measured with high accuracy. Rather than relying on CRL, a parameter that could be markedly affected by fetal posture, it is perhaps time to review our ultrasound practice at 10–14 weeks in the first trimester.

5. Conclusion

In the sonographic assessment of fetal gestational age in the first trimester, the use of a combination of fetal parameters such as BPD, HC, AC, and FL is more accurate than CRL or GA at 10–14 weeks gestation in normal pregnancies. The use of these parameters as references for comparison may also be helpful when fetal abnormality is suspected in early pregnancy.

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Conflict of interest

Nil to declare.

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