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A Method for Estimating Gestational Age of Fetal Remains Based on Long Bone Lengths

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Abstract:	The estimation of gestational age (GA) in fetal human remains is important in forensic settings, particularly to assess fetal viability, in addition to often being the only biological profile parameter that can be assessed with some accuracy for non-adults. The length of long bones diaphysis is one of the most frequently methods used for fetal age estimation. The main objective of this study was to present a simple and objective method for estimating GA based on the measurements of the diaphysis of the femur, tibia, fibula, humerus, ulna and radius. Conventional least squares regression equations (classical and inverse calibration approaches) and quick reference tables were generated. A supplementary objective was to compare the performance of the new formulae against previously published models. The sample comprised 257 fetuses (136 females and 121 males) with known GA (between 12 and 40 weeks) and was selected based on clinical and pathological information. All measurements were performed on radiographic images acquired in anonymous clinical autopsy records from spontaneous and therapeutic abortions in two Portuguese hospitals. The proposed technique is straightforward and reproducible. The models for GA estimation are exceedingly accurate and unbiased. Comparisons between inverse and classical calibration show that both perform exceptionally well, with high accuracy and low bias. Also, the newly developed equations generally outperform earlier methods of GA estimation in forensic contexts. Quick reference tables for each long bone are now available. The obtained models for the estimation of gestational age are of great applicability in forensic contexts.
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A Method for Estimating Gestational Age of Fetal Remains Based on Long Bone Lengths

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ABSTRACT

The estimation of gestational age (GA) in fetal human remains is important in forensic settings, particularly to assess fetal viability, in addition to often being the only biological profile parameter that can be assessed with some accuracy for non-adults. The length of long bones diaphysis is one of the most frequently methods used for fetal age estimation.

The main objective of this study was to present a simple and objective method for estimating GA based on the measurements of the diaphysis of the femur, tibia, fibula, humerus, ulna and radius. Conventional least squares regression equations (classical and inverse calibration approaches) and quick reference tables were generated. A supplementary objective was to compare the performance of the new formulae against previously published models. The sample comprised 257 fetuses (136 females and 121 males) with known GA (between 12 and 40 weeks) and was selected based on clinical and pathological information. All measurements were performed on radiographic images acquired in anonymous clinical autopsy records from spontaneous and therapeutic abortions in two Portuguese hospitals.

The proposed technique is straightforward and reproducible. The models for GA estimation are exceedingly accurate and unbiased. Comparisons between inverse and classical calibration show that both perform exceptionally well, with high accuracy and low bias. Also, the newly developed equations generally outperform earlier methods of GA estimation in forensic contexts. Quick reference tables for each long bone are now available. The obtained models for the estimation of gestational age are of great applicability in forensic contexts.

KEYWORDS: fetus, age estimation, long bones, radiography, regression equations

INTRODUCTION

The development of methods for the appropriate study of skeletal remains of deceased fetuses and newborns has been fraught by the shortage of identified osteological collections [1]. Despite this limitation, several studies have attempted to provide reliable methods that allow the construction of the biological profile of fetuses [2-17].

Frequently, estimated age (which corresponds to gestational age [GA]) in fetal remains through anthropological examination is the single obtainable parameter of the biological profile [1, 15, 18]. Age of fetal human skeletal remains has been recurrently estimated from long bone diaphyseal length, using different empirical approaches [2, 4, 7]. Although dental age is usually more accurate than skeletal age, for fetuses, taking into account that crown mineralisation only occurs between the 3rd and 4th months and due to their very small size, bone age becomes, in many instances, the only available method [19].

The state of preservation of deceased individuals in a legal context is of vital concern to Forensic Anthropology (FA). The forensic anthropologist is frequently involved in the analysis of cadaveric remains in different states of preservation – the belief that FA only focus on skeletonized remains is no longer tenable – including remains with soft tissues, from intact and well preserved corpses to cadaverous remains with different states of concomitant preservation, or dismembered bodies [20, 21]. In order to address this contextual paradigm, the current study was designed considering the application of FA methodologies both to skeletonized and non-skeletonized human remains.

As such, the main goal of this study was to update fetal radiographic data using a validated method [4], providing a simple and objective methodology to calculate fetal and newborn GA from the length of long bone shafts (namely the humerus, radius, ulna, femur, tibia, and fibula). In order to fulfil this objective, Portuguese population based equations for each of the diaphyses were established using conventional least squares regression (inverse calibration and classical calibration procedures were both employed and compared). Also, reference tables to simplify gestational age estimation were created for each bone. An ancillary objective was to ascertain the operational reliability of the new formulae in contrast to previously published work by other authors [4, 10, 14].

MATERIALS & METHODS

This retrospective cohort study was based on a validated method, using plain radiographs (XR) from fetuses of known gestational age (established by maternal menstrual history and first trimester sonographic data). XR measurements were

preferred over ultrasound measurements, as they are more reliable and can easily be used when the subject of study (in forensic context, for instance) retains soft tissues [4, 5, 22]. XR records were collected in a hospital background; as such, the fetuses belong to an identified sample, which is of great empirical value to develop population-specific aging techniques [3-5].

Anonymous fetopathological clinical autopsy records from spontaneous and therapeutic abortions (i.e., none of the fetuses was born alive), performed at Hospital Garcia de Orta, E.P.E. (HGO, Almada, Portugal) and Hospital Fernando da Fonseca, E.P.E. (HFF, Amadora, Portugal) were collected. All abortions occurred between 2006 and 2014. Plain radiographs and autopsies abide to the ethical guidelines from both hospitals, as well as data handling in further investigations. The study did not involve additional manipulation of the fetuses.

The sample used consists of 257 fetuses (121 males; 136 females) with an age range between 12 and 40 weeks of gestational age. The mean age at death was 24.49 weeks (SD = 7.86). The selection of the fetuses was made according to the following criteria:

- GA between 12 and 40 weeks;
- Absence of external limb malformation;
- Absence of pathological alterations which could compromise normal skeletal growth (e.g., Intra Uterine Growth Restriction);
- Lack of maternal pathology;
- Time elapsed between intrauterine death and fetal expulsion inferior to a week;
- Twin pregnancies were included only when there were no signs of discordant growth.

Post-mortem radiographs (XR) were taken with a Siemens Mobilett II equipment (HGO), and an Iconos R200 or Multix Fusion (HFF) (Global Siemens Healthcare Headquarters - Siemens AG, Healthcare Sector, Henkestrasse 127, D-91052 Erlangen, Germany) with exposure times of 42 – 55 Kv and 2 – 5 mAseg, contingent to fetal age. XR were subsequently stored in the Centricity® Radiology software (General Electric Company©, GE Healthcare Global Headquarters, Pollards Wood, Nightingales Lane, Chalfont St. Giles HP8 4SP, United Kingdom).

Measurements of the diaphyseal (i.e., the ossified shaft of the developing bone [4]) length of the long bones chosen for this study were taken with Screen Calipers 4.0 (Iconico, Inc. ©). Whenever necessary, the obtained value was converted to scale (included in the XR). As a rule, the measurements were performed on the left side, with the fetus placed in anteroposterior position, otherwise the measurements were taken with the fetus placed laterally (Figure 1). The calculation of GA was made in weeks,

following the standard terminology used in obstetrics [23-25] and forensic sciences [26]. Classical formulae calculate GA in lunar months [10, 27].

Fig 1 Example of measurement with screen caliper on typical radiographic images – anteroposterior position and lateral position

All statistical analyses were performed with IBM® SPSS® (version 21.0). Gestational age and the longitudinal dimensions of long bones were treated as continuous variables. Descriptive statistics, namely group means, standard deviation (SD) and 95% confidence intervals (95% CI) for the mean, were estimated for each continuous variable. The normal distribution of the variables was assessed through the skewness and kurtosis of the distributions [28]. All the variables are modeled by a normal distribution. The homogeneity of variances was assessed with a Levene's test. A subset of 30 individuals was randomly selected in order to analyze intra- and interobserver measurement error. The first author (CC) completed the measurements in two different sessions. A second observer (FC) executed all the measurements in the same individuals. The reliability of the method was evaluated with the relative Technical Error of Measurement (rTEM) [29, 33]. A *student's t-test* for independent samples was used to evaluate the null hypothesis that the length of long bones in sexual groups was equal. Conventional least squares regression analysis was applied to estimate gestational age at death. The simplest structure of regression (single linear regression) assumes a linear relation between two variables, and can be expressed by the equation,

$$y = a + bx + e$$

where *x* is the independent variable; *y* is the dependent variable; *a* is the value of *y* when *x* equals zero; *b* is the slope in *y* with *x*; and *e* is the random error in *y* [31]. It is presumed that the dependent variable presents a statistical uncertainty and that the errors show a normal distribution around the true values with constant variance, while *x* is error-free or almost [30]. Both classical and inverse calibration models were used to predict gestational age at death. In the linear inverse calibration model, gestational age is used as the response variable (*y*) and diaphysis length as the independent, or predictor, variable (*x*). In classical calibration, *x* is the variable for which estimates are to be made, and not *y* as in inverse regression analysis [31]. In this case, that means that GA is *x* and the diaphysis length is *y* and a regression of GA on the length of long bone diaphysis is executed.

The reliability (accuracy and bias) of classical and inverse calibration models was compared in a validation sample (N=30) – i.e., a sample of fetuses that were not used

to construct the equations. The performance of the equations generated in this study was also compared with previously published aging techniques from the diaphyseal length of fetal remains [3, 4, 10,13].

Accuracy was evaluated through the mean absolute error (MAE) [32], as follows:

$$\mathrm{MAE} = \Sigma\,|\text{estimated GA} - \text{documented GA}|/\mathrm{N}$$

Bias (or systematic error) was calculated using the mean error (ME) [32]:

$$\mathrm{ME} = \Sigma\,(\text{estimated GA} - \text{documented GA})/\mathrm{N}.$$

RESULTS

In order to control the accuracy and precision of the measurements, intraobserver (repeatability) and interobserver (reproducibility) errors were calculated using the relative Technical Error of Measurement [29, 33]. Measurement error results are epitomized in Table 1.

Table 1 Relative Technical Error of Measurement (rTEM) with Intraobserver and Interobserver values for each of the six bones inthe study.

Long bones diaphyseal length is not significantly different between males and females (Table 2); as such, the sexes were pooled together to build the linear models.

Table 2 Results of the Student's t test (t) comparing male and female, degrees of freedom (DF), mean difference and standard error difference.

All bones present a very strong positive correlation between longitudinal length and documented GA. The correlation between femoral length and GA was the strongest (Figure 2). Femoral diaphysis length also provides the best estimate of gestational age considering both SEE (2.00) and MSE (1.51). On the whole, the radius presented the largest amount of error (Inverse Calibration: adjusted R^2 = 0.900; SEE = 2.48 / Classical Calibration: adjusted R^2 = 0.900; MSE =1.98). Multivariable models were not considered due to multicollinearity problems. The linear models for each of the long bones are summarized in Tables 3 (inverse calibration) and 4 (classical calibration).

Fig 2: Linear correlation between femoral length and gestational age.

Table 3 Inverse Calibration Regression Equations obtained for each bone in study, correspondent standard error of the estimate (SEE), adjusted $R^2$and number of cases studied (N).

Table 4 Classical Calibration Regression Equations obtained for each bone in study, correspondent mean standard error (MSE), adjusted R^2 and number of cases studied (N).

The descriptive statistics forthe diaphyseal length of each long bone, divided in six age groups (in weeks of gestation), are available in quick reference tables (Tables 5 – 10). These tables include the mean length of each bone, the standard error with a 95% confidence interval and the number of cases studied.

Table 5 Reference table for femur length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

Table 6 Reference table for tibia length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

Table 7 Reference table for fibula length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

Table 8 Reference table for humerus length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

Table 9 Reference table for ulna length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

Table 10 Reference table for radius length growth including mean length, number of cases studied (N), standard deviation, standard error, 95% confidence interval for mean, minimum and maximum length in each age group.

In order to validate the equations, they were tested in a different sample. Therefore, to avoid methodological bias, 30 fetuses of documented gestational age not included in the original regression analyses were used to evaluate the reliability to estimate GA in

fetal remains of both classical and inverse regression models. Both models are very accurate, although showing a negligible tendency to overestimate GA. Accuracy (using mean absolute difference as surrogate) is usually slightly better in the inverse calibration models, with the regression formula for the femur performing especially well. On the other hand, bias is marginally smaller in the classical calibration models – except for the femur. The accuracy of the new regression equations was also compared with equivalent formulae developed by Adalian (2001), Adalian et al (2001) and Scheuer et al (1980) [3, 4, 14]. The results of the application of Fazekas and Kósa's models (1978) [10] were also equated, as they are recurrently applied in forensic contexts. The major problem with this procedure is that it first calculates body length and only then GA – with the age range in lunar months. As such, the GA was converted to weeks. As a rule, the new models performed better, presenting a higher accuracy and a smaller bias – closely followed by Adalian's models [3, 4]. Models by Scheuer et al. [14] were the least accurate and the most biased. All results are epitomized in Table 11.

Table 11 Mean absolute difference (MAD) and bias obtained when comparing the new equations (classical and inverse regression models) with equivalent formulae developed by Adalian (2001), Scheuer et al (1980) and Fazekas and Kósa (1978), for each diaphysis studied

DISCUSSION

The estimation of gestational age is often the only attainable parameter of the biological profile in fetal remains. As such, it is essential to generate reliable methods for the estimation of gestational age in fetuses both in forensic [3-5, 7] and archaeological contexts [34]. Until recently, Fazekas and Kosa (1978) [10] were the only references available for the forensic community though it was evident that they were not that adequate. More recently, authors such as Adalian (2001) [3, 4] published new references and the same was done by us [7], on the basis of a smaller sample and based in less diaphysis.

Measurement protocol is reproducible, with the measurements accomplished within appropriate levels of measurement error – for both the same and different observers. The fetal and perinatal autopsy usually integrates skeletal radiographs [35], which are less prone to measurement error than ultrasonographic images [4, 5, 22]. Also, in forensic contexts, a radiographic approach should be favored when skeletal preparation is unfeasible in practice or socially objectionable [5].

Descriptive data displays a consistent pattern of skeletal growth among individuals who died during the perinatal period – although there is slightly greater growth acceleration, less perceptible in the femur and the tibia, between the twelfth and the 22nd week of gestation. There is a stronglinear relationship between gestational age and the length of long bones, in accordance with previous radiological and sonographic studies [6, 23-25, 36].

Gestational age estimation formulae were established for the sexes combined, acknowledging the statistical undifferentiated length of long bones diaphyses between sexes. Linear calibration models (both inverse and classical calibration) for the different long bones generated accurate predictions of GA, with the femur and the tibia conveying the best estimates. This is especially relevant as the bones from the lower limb are usually the most well-preserved skeletal elements [37]. Inverse calibration models show a better, but negligible, accuracy in the estimation of GA – which is theoretically expected since this approach produces lesser mean quadratic errors in interpolations [30]. On the contrary,systematic bias is smaller, although slightly, in the classical calibration models, excluding the femur. An artifact in the construction of the linear model – namely the asymmetry in the treatment of variables, in which age is considered the dependent variable – leads to significant biases in the skeletal estimation of age [31,38]. Typically, there is a regression towards the mean effect that will cause an overestimation of age in younger individuals, and an underestimation in older individuals [31, 34, 39]. In any case, both models (classical calibration and inverse calibration) perform exceptionally well, with high accuracy and low bias. This is particularly obvious in the case of the femur. Inverse and classical calibration models are not homologous or transposable, but they are related, and share the same coefficient of determination [30]: when this coefficient comes close to 1, as in the case of most linear models fitted in this study (adjusted R^2 always equal or superior to 0.9), the difference between the classical and inverse procedures is minimized [38, 37]. In simple terms, the higher the correlation, the lesser is the bias [31].

The newly developed linear equations outperform previously published methods of fetal gestational age estimation – except in the case of the humerus – in a holdout sample. In general, Adalian's equations [3, 4] performed almost as well as the new regression models, which can be justified by sample and methodological similarities: anonymous fetopathologic examination records of recent fetuses with known GA, in a European hospital context, with the employment of inverse calibration to construct gestational age prediction equations. Interestingly, Fazekas and Kósa's equations [10] were also highly accurate and unbiased, in spite of their acknowledged methodological limitations, namely the unknown fetal gestational age of the sample and the use of a "two step

procedure" in which bone length is converted in body size and only then transformed into GA. Finally, reference models proposed by Scheuer et al. [14] were less exact and more biased. Even though the methodology is similar to the one used in this study (and also to Adalian's procedural technique [3, 4]), the sample is utterly different, encompassing only individuals that died between 24 weeks of GA and six post-natal weeks. As such, Scheuer et al. [14] technique may not be suitable for younger fetuses. Furthermore, the validation of the regression equations here developed provided good results, proving their usefulness.

FINAL REMARKS

The newly proposed models for GA estimationfrom long bones length are very accurate and unbiased, both in the classical and inverse regression approaches. The procedural technique is easily applicable and reproducible, and appropriate for settings involving, not only dry bones, but also semi-decomposed remains. No differences in measurements were established between sexes, suggesting that sex-specific references for these particular skeletal measurements are not required. Quick reference tables for each long bone are also available for a fetal sample of Portuguese origin.

Limitations of this study include the clinical determination of gestational age based on maternal menstrual history and ultrasound data and the cross-sectional nature of the data. The submitted models should undergo supplementary confirmation in independent fetal material (especially in skeletal dry remains) in order to confirm their reliability in forensic and bioarcheological contexts.

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Figures

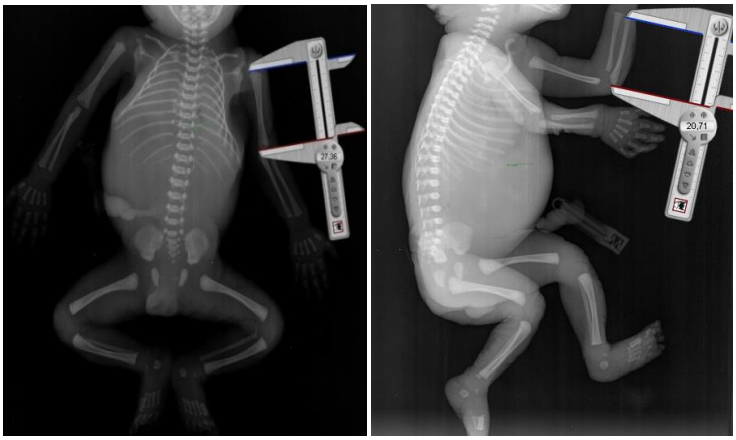

Figure 1

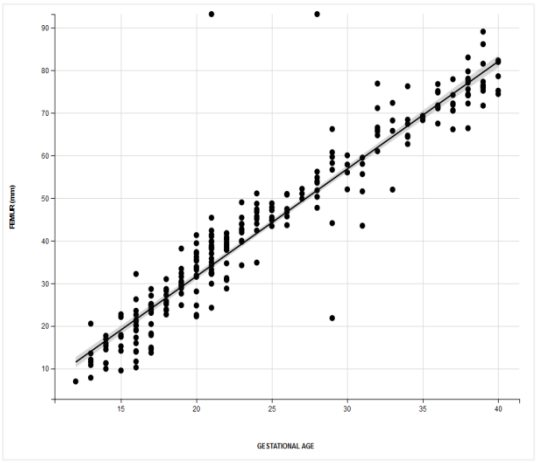

Figure 2

Table 1

Bone	Intraobserver Error (rTEM)	Interobserver Error (rTEM)
Femur	0.64%	1.02%
Tibia	0.73%	1.82%
Fibula	0.59%	1.48%
Humerus	0.57%	1.42%
Ulna	0.55%	1.52%
Radius	0.57%	1.20%

Table 2

Bone	*t*	DF	*p*	Mean Difference	Std. Error Difference
Femur	0.512	253	0.609	1.323	2.583
Tibia	0.673	251	0.502	1.510	2.245
Fibula	0.777	239	0.438	1.681	2.163
Humerus	0.689	254	0.491	1. 438	2.087
Ulna	0.600	252	0.549	1.189	1.984
Radius	0.666	252	0.506	1.149	1.725

Table 3

Bone	Regression Equation	SEE	Adjusted R^2	N
Femur	$\mathrm{GA} = 8.525 + (0.372 \times \text{femur length})$	2.00	0.936	255
Tibia	$\mathrm{GA} = 8.514 + (0.428 \times \text{tibia length})$	2.12	0.928	253
Fibula	$\mathrm{GA} = 8.603 + (0.451 \times \text{fibula length})$	2.22	0.920	241
Humerus	$\mathrm{GA} = 6.814 + (0.452 \times \text{humerus length})$	2.31	0.913	256
Ulna	$\mathrm{GA} = 7.278 + (0.474 \times \text{ulna length})$	2.23	0.910	254
Radius	$\mathrm{GA} = 7.003 + (0.542 \times \text{radius length})$	2.48	0.900	254

Measurements are in mm; standard error of the estimate (SEE) in weeks.

Table 4

Bone	Regression Equation	MSE	Adjusted R^2	N
Femur	$\mathrm{GA} = \frac{\text{femur length} + 18.72}{2.52}$	1.51	0.936	255
Tibia	$\mathrm{GA} = \frac{\text{tibia length} + 15.76}{2.17}$	1.69	0.928	253
Fibula	$\mathrm{GA} = \frac{\text{fibula length} + 14.72}{2.04}$	1.79	0.920	241
Humerus	$\mathrm{GA} = \frac{\text{humerus length} + 10.40}{2.02}$	1.85	0.913	256
Ulna	$\mathrm{GA} = \frac{\text{ulna length} + 10.71}{1.92}$	1.88	0.910	254
Radius	$\mathrm{GA} = \frac{\text{radius length} + 8.42}{1.66}$	1.98	0.900	254

Measurements are in mm; mean standard error (MSE) in weeks.

Table 11

		Inverse calibration	Classical calibration	Scheuer et al	Adalian	Fazekas&Kósa
Femur (N=30)	MAD	0.049	0.056	0.143	0.058	0.070
	Bias	0.004	-0.004	0.138	0.006	-0.043
Tibia (N=29)	MAD	0.056	0.060	0.127	0.066	0.071
	Bias	0.009	0.002	0.102	0.008	-0.050
Fibula (N=27)	MAD	0.067	0.070	---	0.075	0.072
	Bias	0.011	0.005	---	0.139	-0.056
Humerus (N=30)	MAD	0.060	0.067	0.102	0.067	0.053
	Bias	0.009	0.001	0.078	-0.001	-0.004
Ulna (N=29)	MAD	0.068	0.075	0.098	0.084	0.070
	Bias	0.008	0.003	0.062	0.010	0.001
Radius (N=30)	MAD	0.070	0.078	0.099	0.088	0.111
	Bias	0.011	0.008	0.076	0.256	0.098

Table 5

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the femur (mm)	12-16 weeks	40	16.5395	5.31198	.83990	14.8406	18.2384	6.99	32.20
	17-20 weeks	55	27.9322	6.14977	.82923	26.2697	29.5947	13.72	41.31
	21-24 weeks	60	38.9478	5.48190	.70771	37.5317	40.3640	24.28	51.10
	25-28 weeks	23	49.1048	3.65238	.76157	47.5254	50.6842	43.44	56.20
	29-32 weeks	23	57.9909	10.99865	2.29338	53.2347	62.7470	21.85	76.87
	33-36 weeks	21	68.8538	5.46467	1.19249	66.3663	71.3413	52.00	76.76
	37-40 weeks	33	76.1209	4.98254	.86735	74.3542	77.8876	66.14	89.06
	Total	255	42.9641	20.52501	1.28533	40.4328	45.4953	6.99	89.06

Table 6

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the tibia (mm)	12-16 weeks	40	14.1297	4.79881	.75876	12.5950	15.6645	5.06	29.17
	17-20 weeks	54	24.3572	5.69413	.77487	22.8030	25.9114	11.36	35.49
	21-24 weeks	59	34.1944	4.92077	.64063	32.9120	35.4768	22.68	45.13
	25-28 weeks	23	43.0609	3.67538	.76637	41.4715	44.6502	38.01	50.93
	29-32 weeks	23	49.8974	9.14683	1.90725	45.9420	53.8528	18.85	61.30
	33-36 weeks	21	59.9652	5.27462	1.15102	57.5643	62.3662	46.00	68.57
	37-40 weeks	33	65.3667	4.44355	.77352	63.7911	66.9423	59.66	75.75
	Total	253	37.3611	17.77639	1.11759	35.1601	39.5621	5.06	75.75

Table 7

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the fibula (mm)	12-16 weeks	34	13.0732	4.63507	.79491	11.4560	14,6905	4.70	27.66
	17-20 weeks	51	22.8569	5.63507	.78907	21.2720	24,4418	9.83	36.05
	21-24 weeks	57	32.5491	4.77234	.63211	31.2828	33,8154	21.26	42.90
	25-28 weeks	23	41.1974	3.54873	.73996	39.6628	42,7320	35.83	49.51
	29-32 weeks	23	47.5322	8.74690	1.82385	43.7497	51,3146	18.10	58.61
	33-36 weeks	21	56.9867	4.69465	1.02446	54.8497	59,1236	44.20	64.57
	37-40 weeks	32	61.2763	4.25708	.75255	59.7414	62,8111	54.90	71.71
	Total	241	35.9495	16.74171	1.07843	33.8251	38,0739	4.70	71.71

Table 8

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the humerus (mm)	12-16 weeks	39	16.6205	5.05318	.69395	15.0844	18.3552	7,63	32.09
	17-20 weeks	55	27.1211	5.57566	.48403	25.6582	28.6186	14.18	38.46
	21-24 weeks	61	36.9577	4.67909	.46366	35.8200	38.1455	23.83	46.76
	25-28 weeks	24	44.2875	4.816161	1.06767	42.1555	46,1314	28,78	52.79
	29-32 weeks	23	51.3013	8.89843	2.30569	47.3978	54.6611	21.07	64.42
	33-36 weeks	21	60.3967	4.37626	.85652	58.6440	62.1649	47.90	66.41
	37-40 weeks	33	64.9403	3.87704	.57008	63.6098	66.3180	57.01	75.52
	Total	256	39.2127	16.2758	.86140	30.5659	33.9587	7.63	75.52

Table 9

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the ulna (mm)	12-16 weeks	38	14.8442	4.80095	.71054	13.4252	16.4812	6.41	29.71
	17-20 weeks	55	24.9264	5.31213	.52047	23.5081	26.4101	11.88	36.61
	21-24 weeks	60	34.3445	4.81384	.48120	33.1807	35.5202	22.25	46.32
	25-28 weeks	24	40.7929	4.74810	1.14426	38.7502	42.5360	24.72	47.61
	29-32 weeks	23	47.3096	8.40582	2.27873	43.6813	50.4480	18.10	58.75
	33-36 weeks	21	56.0910	4.25888	.65372	54.2918	57.9765	45.70	63.30
	37-40 weeks	32	60.9956	4.13295	.55193	59.6024	62.5122	53.66	71.39
	Total	254	36.2643	15.76467	.98931	34.3176	38.2142	6.41	71.39

Table 10

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Length of the radius (mm)	12-16 weeks	39	13.7682	4.36241	.57007	12.5388	15.1897	4.70	26.25
	17-20 weeks	55	22.4218	4.60720	.42461	21.2599	23.6294	11.59	31.83
	21-24 weeks	60	30.6027	4.41685	.44854	29.5263	31.7592	18.20	41.87
	25-28 weeks	24	36.0133	4.26564	.94969	34.0862	37.5954	21.89	43.06
	29-32 weeks	23	42.5126	8.21386	1.84553	39.4040	45.7737	19.60	64.56
	33-36 weeks	21	49.5333	3.98735	.49828	47.7900	51.1059	41.20	56.20
	37-40 weeks	32	53.3122	3.65320	.50755	52.1707	54.6831	47.23	62.44
	Total	254	32.2623	13.72842	.86140	12.79378	14.64544	4.70	64.56