

Charts of fetal size: limb bones

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Objective To construct new size charts for all fetal limb bones.

Design A prospective, cross sectional study.

Setting Ultrasound department of a large hospital.

Sample 663 fetuses scanned once only for the purpose of the study at gestations between 12 and 42 weeks.

Methods Centiles were estimated by combining separate regression models fitted to the mean and standard deviation, assuming that the measurements have a normal distribution at each gestational age.

Main outcome measures Determination of fetal limb lengths from 12 to 42 weeks of gestation.

Results Size charts for fetal bones (radius, ulna, humerus, tibia, fibula, femur and foot) are presented and compared with previously published data.

Conclusions We present new size charts for fetal limb bones which take into consideration the increasing variability with gestational age. We have compared these charts with other published data; the differences seen may be largely due to methodological differences. As standards for fetal head and abdominal measurements have been published from the same population, we suggest that the use of the new charts may facilitate prenatal diagnosis of skeletal dysplasias.

INTRODUCTION

Measurement of fetal limbs can be used to date pregnancies as well as forming an important part of the assessment of fetal anatomy. The femur length is the most commonly used limb measurement and is usually included as a routine part of any fetal anomaly scan. However, when signs indicating the possibility of a skeletal dysplasia (short femur, small chest, hypomineralisation, *etc.*) are found, more extensive evaluation of all long bones is needed to aid diagnosis. We have previously reported new charts for fetal femur length measurement^{1,2} and here we present charts for other long bones. For completeness, we also include our previously published results for femur length.

METHODS

Sample

The study design, patient selection and methods of analysis have been described elsewhere¹. In brief, this

was a cross sectional study of 665 fetuses measured once only for the purpose of this study in the ultrasound department of King's College Hospital at gestations between 12 and 42 weeks.

Only western European and Afro-Caribbean racial groups were included. All subjects had a known last menstrual period and the ultrasound and menstrual age at 18–20 weeks agreed to within 10 days. Exclusion criteria were maternal disease or medication, which was likely to affect the growth of the fetus (diabetes mellitus, renal disease, hypertension requiring treatment, *etc.*), multiple pregnancies, the presence of a fetal malformation and cases where the neonate was found to have a significant congenital malformation, abnormal karyotype or other disease at birth.

Measurements

Fetuses were scanned only once for the purpose of the study at gestations between 12 and 42 weeks, when up to 20 dimensions were measured. All long bones (radius, ulna, humerus, tibia, fibula and femur) were measured in a plane such that the bone was as close as possible to a right angle to the ultrasound beam. Care was taken to ensure that the full length of the bone was visualised and the view was not obscured by shadowing from adjacent bony parts. Such a view was not always achieved, and thus it was not possible to obtain all measurements on all fetuses. The radius and ulna, tibia and fibula were measured independently. The foot was measured in the plantar view, the measurement being made from the heel to the end of the longest toe.

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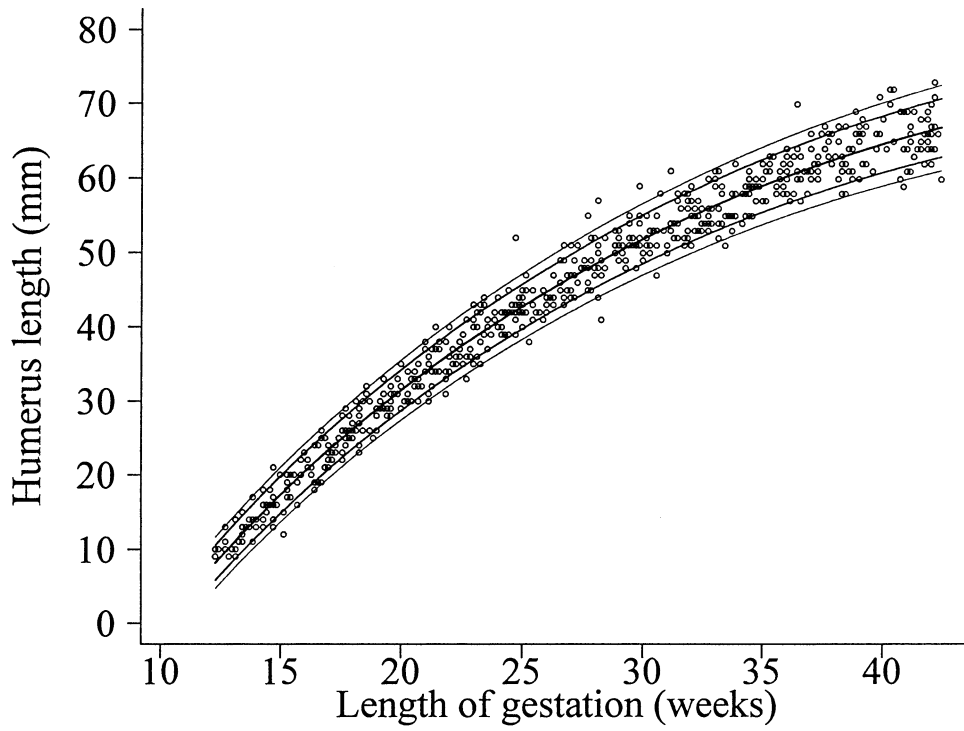


Fig. 1. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for humerus length.

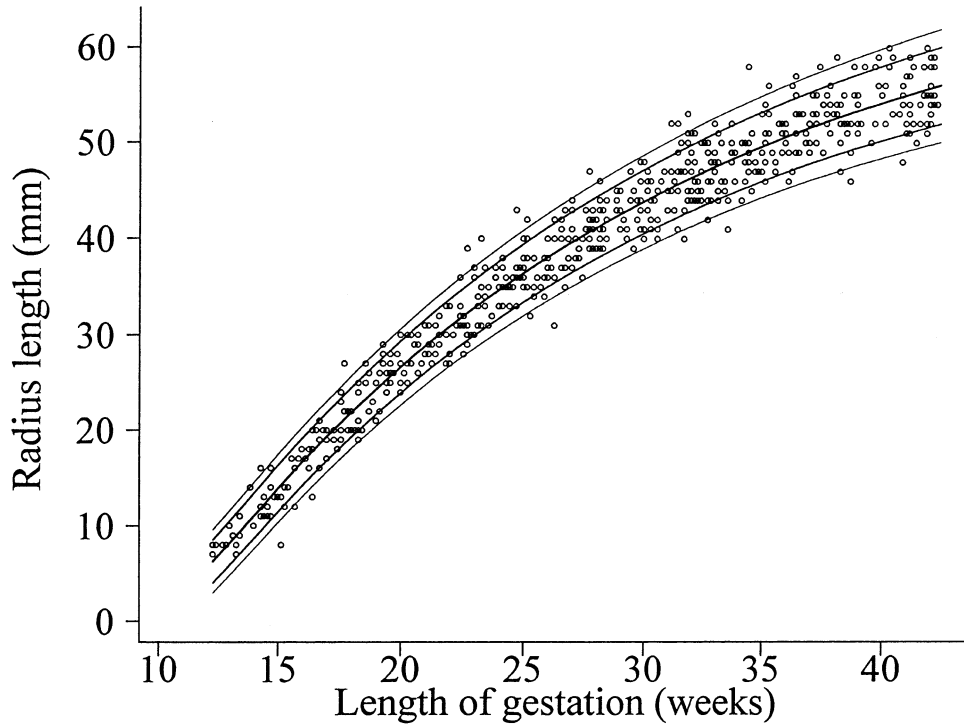


Fig. 2. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for radius length.

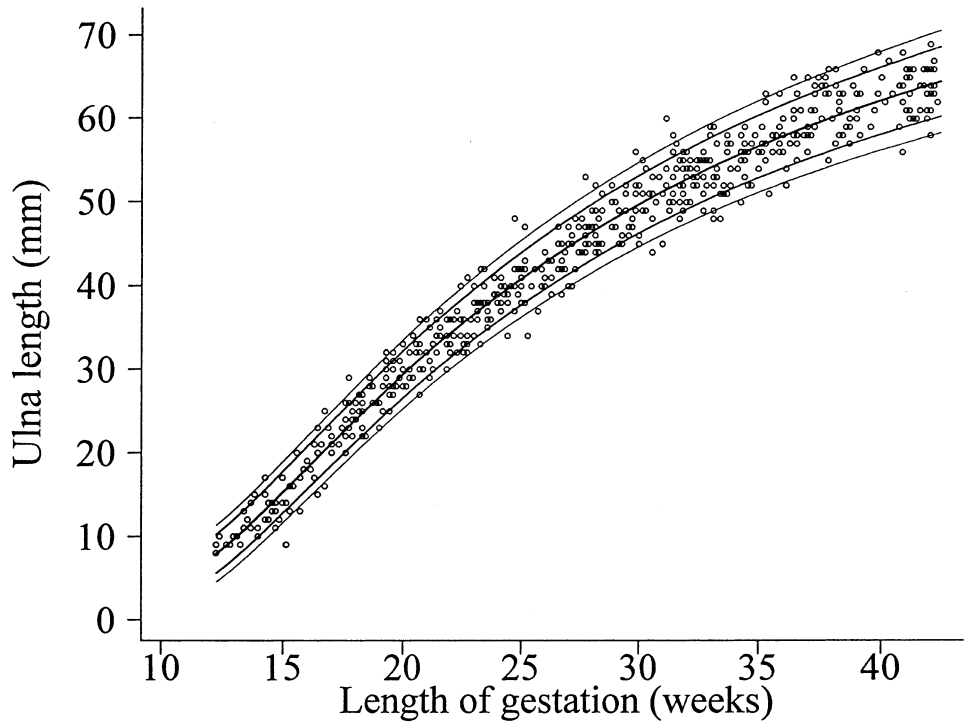


Fig. 3. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for ulna length.

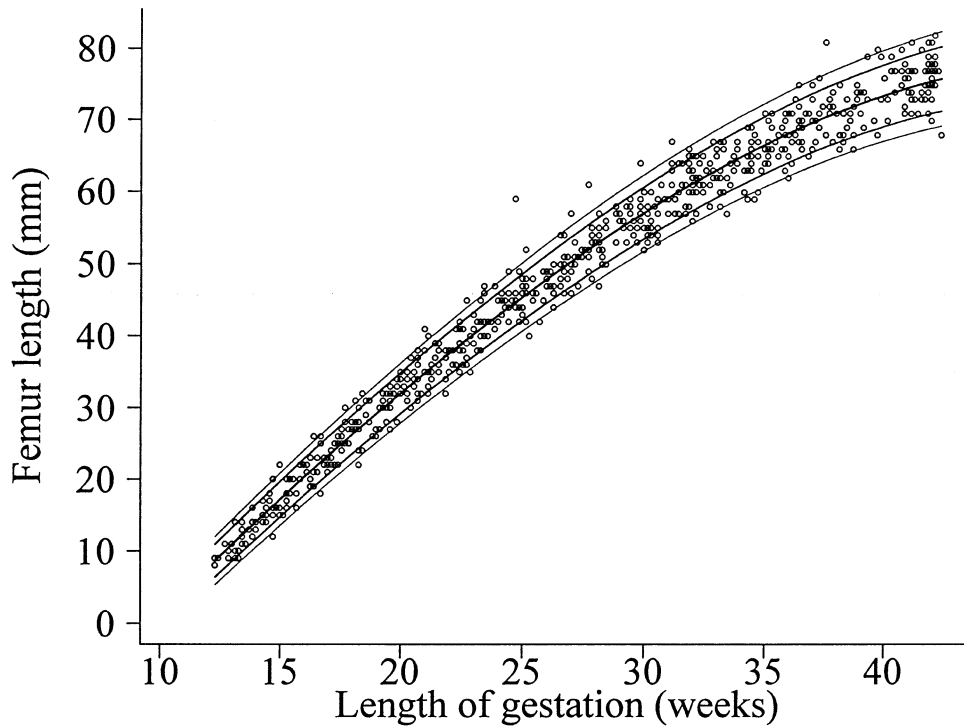


Fig. 4. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for femur length.

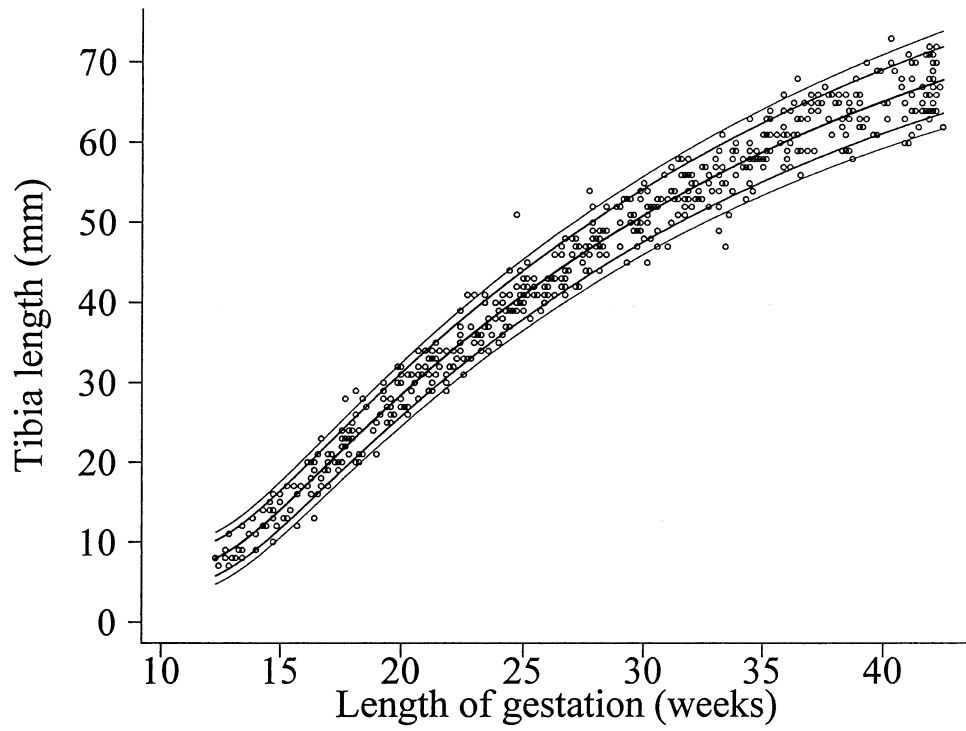


Fig. 5. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for tibia length.

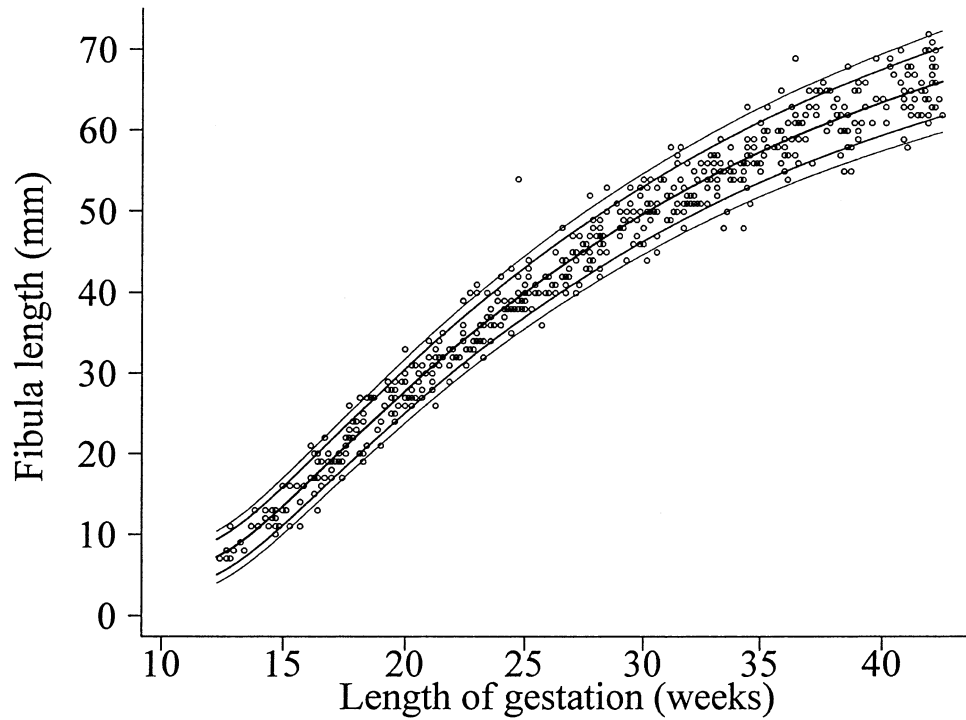


Fig. 6. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for fibula length.

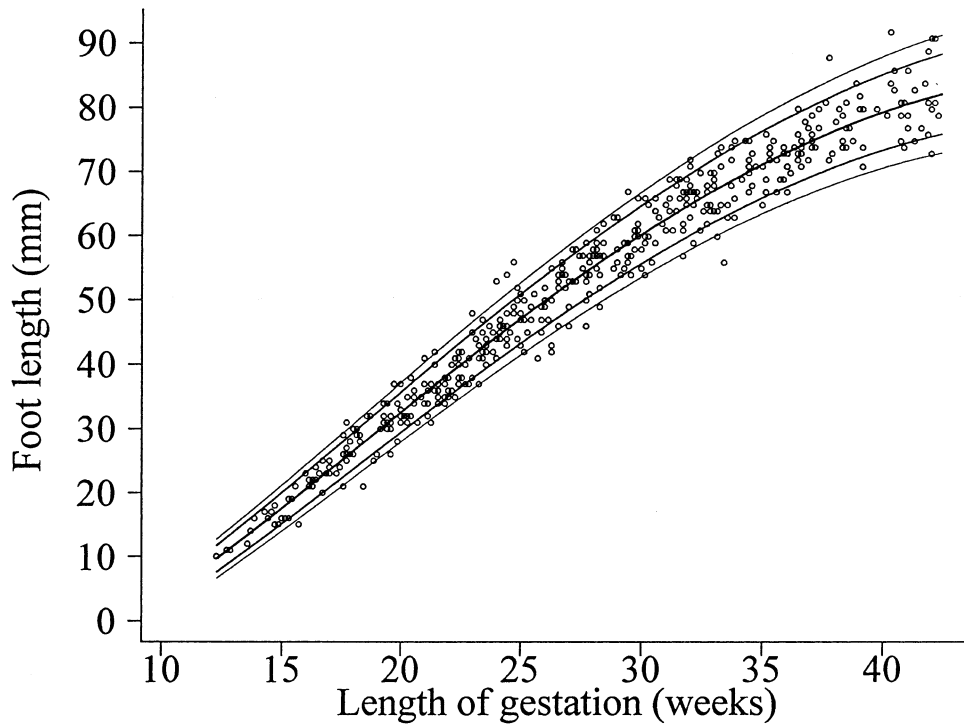


Fig. 7. Fitted 3rd, 10th, 50th, 90th and 97th centiles and raw data for foot length.

Statistical methods

The statistical methods used to analyse the data are described in detail in Altman and Chitty³ and Royston and Wright⁴. In brief, for each measurement, fractional polynomial regression models were fitted separately to estimate the mean and standard deviation (SD) as functions of gestational age. The SD was modelled via the absolute residuals from the regression to estimate the mean. The centiles were obtained by combining these two regression models, making the assumption that at each gestational age, the measurements had a normal distribution. The assumption of normality and the goodness of fit of each regression model were carefully

assessed³. All analyses used individual fetal measurements and exact gestational age. No observations were excluded from the analyses.

RESULTS

Only two of the sample of 665 fetuses were excluded, both because of congenital abnormalities. The number of measurements obtained varied for the different limbs because we only measured bones which were clearly viewed in the appropriate plane.

For each limb measurement, in turn, Figs. 1–7 show the raw data with the 3rd, 10th, 50th, 90th and 97th centiles

Table 1. Fitted 3rd, 10th, 50th, 90th and 97th centiles of humerus length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	8	3.7	4.8	7.1	9.5	10.6	1.8
13	18	7.2	8.3	10.7	13.1	14.2	1.9
14	18	10.5	11.7	14.1	16.5	17.7	1.9
15	14	13.7	14.8	17.3	19.8	21.0	2.0
16	15	16.7	17.9	20.4	23.0	24.2	2.0
17	22	19.6	20.8	23.4	26.0	27.2	2.0
18	18	22.3	23.6	26.2	28.9	30.1	2.1
19	22	24.9	26.2	28.9	31.6	32.9	2.1
20	21	27.4	28.7	31.5	34.2	35.5	2.2
21	22	29.8	31.2	34.0	36.8	38.1	2.2
22	20	32.1	33.5	36.3	39.2	40.5	2.2

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Table 1 (continued)

Weeks of gestation	<i>n</i>	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
23	22	34.3	35.7	38.6	41.5	42.9	2.3
24	24	36.4	37.8	40.7	43.7	45.1	2.3
25	20	38.4	39.8	42.8	45.8	47.2	2.4
26	19	40.3	41.7	44.8	47.9	49.3	2.4
27	24	42.1	43.6	46.7	49.8	51.3	2.4
28	20	43.9	45.3	48.5	51.7	53.2	2.5
29	21	45.5	47.0	50.2	53.5	55.0	2.5
30	19	47.1	48.6	51.9	55.2	56.7	2.6
31	26	48.6	50.2	53.5	56.8	58.4	2.6
32	25	50.0	51.6	55.0	58.4	59.9	2.6
33	23	51.4	53.0	56.4	59.8	61.5	2.7
34	20	52.7	54.3	57.8	61.3	62.9	2.7
35	20	53.9	55.6	59.1	62.6	64.3	2.8
36	24	55.1	56.8	60.3	63.9	65.6	2.8
37	19	56.2	57.9	61.5	65.1	66.8	2.8
38	20	57.2	58.9	62.6	66.3	68.0	2.9
39	14	58.2	60.0	63.7	67.4	69.2	2.9
40	13	59.1	60.9	64.7	68.5	70.3	3.0
41	25	60.0	61.8	65.6	69.5	71.3	3.0
42	17	60.8	62.6	66.5	70.4	72.2	3.0
Total	613						

Table 2. Fitted 3rd, 10th, 50th, 90th and 97th centiles of radius length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	<i>n</i>	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	6	2.2	3.3	5.5	7.8	8.8	1.7
13	8	4.8	5.9	8.2	10.5	11.6	1.8
14	16	7.6	8.7	11.0	13.4	14.5	1.8
15	11	10.3	11.5	13.9	16.3	17.4	1.9
16	12	13.0	14.2	16.7	19.1	20.3	1.9
17	16	15.6	16.8	19.3	21.9	23.1	2.0
18	15	18.1	19.3	21.9	24.5	25.7	2.0
19	24	20.4	21.7	24.4	27.0	28.3	2.1
20	22	22.7	23.9	26.7	29.4	30.7	2.1
21	21	24.8	26.1	28.9	31.6	32.9	2.2
22	19	26.8	28.1	30.9	33.8	35.1	2.2
23	21	28.6	30.0	32.9	35.8	37.1	2.3
24	20	30.4	31.8	34.7	37.7	39.1	2.3
25	22	32.0	33.5	36.5	39.5	40.9	2.4
26	20	33.6	35.0	38.1	41.2	42.6	2.4
27	24	35.1	36.5	39.7	42.8	44.3	2.4
28	21	36.5	38.0	41.2	44.3	45.8	2.5
29	21	37.8	39.3	42.6	45.8	47.3	2.5
30	19	39.0	40.6	43.9	47.2	48.7	2.6
31	26	40.2	41.8	45.1	48.5	50.1	2.6
32	25	41.3	42.9	46.4	49.8	51.4	2.7
33	23	42.4	44.0	47.5	51.0	52.6	2.7
34	19	43.4	45.0	48.6	52.1	53.8	2.8
35	22	44.3	46.0	49.6	53.2	54.9	2.8
36	22	45.2	46.9	50.6	54.3	56.0	2.9
37	18	46.1	47.8	51.6	55.3	57.0	2.9
38	18	46.9	48.7	52.5	56.2	58.0	3.0
39	11	47.7	49.5	53.3	57.2	59.0	3.0
40	14	48.4	50.3	54.2	58.1	59.9	3.0
41	21	49.1	51.0	55.0	58.9	60.8	3.1
42	15	49.8	51.7	55.7	59.7	61.6	3.1
Total	572						

Table 3. Fitted 3rd, 10th, 50th, 90th and 97th centiles of ulna length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	6	3.9	5.0	7.3	9.6	10.7	1.8
13	13	6.2	7.3	9.6	12.0	13.1	1.8
14	15	8.8	9.9	12.4	14.8	15.9	1.9
15	12	11.6	12.8	15.3	17.8	18.9	1.9
16	11	14.5	15.7	18.2	20.8	22.0	2.0
17	18	17.3	18.6	21.2	23.8	25.0	2.0
18	16	20.1	21.4	24.0	26.7	28.0	2.1
19	24	22.8	24.0	26.8	29.5	30.8	2.1
20	22	25.3	26.6	29.4	32.2	33.5	2.2
21	20	27.8	29.1	32.0	34.8	36.2	2.2
22	20	30.1	31.4	34.4	37.3	38.7	2.3
23	21	32.3	33.7	36.6	39.6	41.0	2.3
24	21	34.3	35.8	38.8	41.9	43.3	2.4
25	22	36.3	37.8	40.9	44.0	45.5	2.4
26	20	38.2	39.7	42.8	46.0	47.5	2.5
27	24	39.9	41.5	44.7	47.9	49.5	2.5
28	20	41.6	43.2	46.5	49.8	51.3	2.6
29	21	43.2	44.8	48.2	51.5	53.1	2.6
30	20	44.7	46.3	49.8	53.2	54.8	2.7
31	27	46.2	47.8	51.3	54.8	56.4	2.7
32	25	47.5	49.2	52.7	56.3	58.0	2.8
33	23	48.8	50.5	54.1	57.7	59.4	2.8
34	17	50.0	51.8	55.4	59.1	60.8	2.9
35	21	51.2	53.0	56.7	60.4	62.2	2.9
36	20	52.3	54.1	57.9	61.7	63.5	3.0
37	19	53.4	55.2	59.1	62.9	64.7	3.0
38	17	54.4	56.2	60.2	64.1	65.9	3.1
39	12	55.4	57.2	61.2	65.2	67.1	3.1
40	11	56.3	58.2	62.2	66.3	68.2	3.2
41	20	57.2	59.1	63.2	67.3	69.3	3.2
42	14	58.0	60.0	64.1	68.3	70.3	3.3
Total	572						

Table 4. Fitted 3rd, 10th, 50th, 90th and 97th centiles of femur length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	10	4.4	5.5	7.7	10.0	11.1	1.8
13	18	7.5	8.6	10.9	13.3	14.4	1.8
14	18	10.6	11.7	14.1	16.5	17.6	1.9
15	15	13.6	14.7	17.2	19.7	20.8	1.9
16	20	16.5	17.7	20.3	22.8	24.0	2.0
17	23	19.4	20.7	23.3	25.9	27.2	2.1
18	20	22.3	23.6	26.3	29.0	30.2	2.1
19	25	25.1	26.4	29.2	32.0	33.3	2.2
20	22	27.9	29.2	32.1	34.9	36.3	2.2
21	23	30.6	32.0	34.9	37.8	39.2	2.3
22	22	33.2	34.6	37.6	40.6	42.0	2.3
23	22	35.8	37.2	40.3	43.4	44.8	2.4
24	25	38.3	39.8	42.9	46.1	47.6	2.5
25	22	40.8	42.3	45.5	48.7	50.2	2.5
26	22	43.1	44.7	48.0	51.3	52.8	2.6
27	24	45.4	47.0	50.4	53.8	55.3	2.6

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Table 4 (continued)

Weeks of gestation	<i>n</i>	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
28	20	47.6	49.3	52.7	56.2	57.8	2.7
29	22	49.8	51.4	55.0	58.5	60.1	2.8
30	21	51.8	53.5	57.1	60.7	62.4	2.8
31	27	53.8	55.5	59.2	62.9	64.6	2.9
32	26	55.7	57.4	61.2	64.9	66.7	2.9
33	23	57.5	59.3	63.1	66.9	68.7	3.0
34	20	59.2	61.0	64.9	68.8	70.6	3.0
35	22	60.8	62.6	66.6	70.6	72.4	3.1
36	25	62.3	64.2	68.2	72.3	74.1	3.2
37	19	63.7	65.6	69.7	73.8	75.8	3.2
38	21	64.9	66.9	71.1	75.3	77.3	3.3
39	14	66.1	68.1	72.4	76.7	78.7	3.3
40	15	67.2	69.2	73.6	77.9	79.9	3.4
41	26	68.1	70.2	74.6	79.0	81.1	3.5
42	17	69.0	71.1	75.6	80.1	82.2	3.5
Total	649						

Table 5. Fitted 3rd, 10th, 50th, 90th and 97th centiles of tibia length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	<i>n</i>	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	7	4.4	5.4	7.6	9.8	10.8	1.7
13	9	5.8	6.9	9.2	11.4	12.5	1.8
14	14	8.0	9.1	11.4	13.7	14.8	1.8
15	11	10.6	11.7	14.1	16.4	17.6	1.9
16	16	13.3	14.5	16.9	19.4	20.5	1.9
17	20	16.2	17.4	19.9	22.4	23.5	2.0
18	15	19.0	20.2	22.8	25.4	26.6	2.0
19	22	21.8	23.1	25.7	28.3	29.6	2.1
20	20	24.5	25.8	28.5	31.2	32.5	2.1
21	21	27.2	28.5	31.2	34.0	35.3	2.2
22	16	29.7	31.0	33.8	36.7	38.0	2.2
23	18	32.1	33.5	36.4	39.2	40.6	2.3
24	22	34.4	35.8	38.8	41.7	43.1	2.3
25	21	36.6	38.0	41.0	44.1	45.5	2.4
26	20	38.7	40.1	43.2	46.3	47.8	2.4
27	21	40.7	42.2	45.3	48.5	49.9	2.5
28	17	42.6	44.1	47.3	50.5	52.0	2.5
29	21	44.4	45.9	49.2	52.5	54.0	2.6
30	17	46.1	47.7	51.0	54.3	55.9	2.6
31	23	47.7	49.3	52.7	56.1	57.7	2.7
32	21	49.3	50.9	54.4	57.8	59.5	2.7
33	21	50.8	52.4	55.9	59.5	61.1	2.8
34	19	52.2	53.9	57.5	61.0	62.7	2.8
35	19	53.5	55.2	58.9	62.6	64.3	2.9
36	20	54.8	56.6	60.3	64.0	65.7	2.9
37	14	56.0	57.8	61.6	65.4	67.2	3.0
38	18	57.2	59.0	62.9	66.7	68.5	3.0
39	11	58.3	60.2	64.1	68.0	69.8	3.1
40	12	59.4	61.3	65.2	69.2	71.1	3.1
41	22	60.4	62.3	66.4	70.4	72.3	3.2
42	16	61.4	63.3	67.4	71.6	73.5	3.2
Total	544						

Table 6. Fitted 3rd, 10th, 50th, 90th and 97th centiles of fibula length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	5	3.6	4.6	6.8	9.0	10.0	1.7
13	5	5.2	6.2	8.5	10.7	11.8	1.7
14	11	7.4	8.5	10.8	13.1	14.2	1.8
15	10	10.0	11.1	13.5	15.9	17.0	1.9
16	15	12.8	14.0	16.4	18.8	20.0	1.9
17	19	15.6	16.8	19.3	21.8	23.0	2.0
18	14	18.4	19.7	22.2	24.8	26.0	2.0
19	21	21.2	22.4	25.1	27.7	29.0	2.1
20	19	23.9	25.1	27.9	30.6	31.8	2.1
21	21	26.4	27.7	30.5	33.3	34.6	2.2
22	17	28.9	30.2	33.1	35.9	37.3	2.2
23	19	31.2	32.6	35.5	38.5	39.8	2.3
24	24	33.5	34.9	37.9	40.9	42.3	2.3
25	19	35.6	37.0	40.1	43.2	44.6	2.4
26	21	37.6	39.1	42.2	45.4	46.8	2.4
27	21	39.6	41.1	44.3	47.5	49.0	2.5
28	17	41.4	42.9	46.2	49.5	51.0	2.6
29	21	43.1	44.7	48.0	51.4	52.9	2.6
30	20	44.8	46.4	49.8	53.2	54.8	2.7
31	23	46.4	48.0	51.5	54.9	56.6	2.7
32	21	47.9	49.5	53.1	56.6	58.3	2.8
33	20	49.3	51.0	54.6	58.2	59.9	2.8
34	20	50.7	52.4	56.1	59.7	61.5	2.9
35	20	52.0	53.7	57.5	61.2	63.0	2.9
36	20	53.2	55.0	58.8	62.6	64.4	3.0
37	14	54.4	56.2	60.1	64.0	65.8	3.0
38	18	55.5	57.4	61.3	65.3	67.1	3.1
39	10	56.6	58.5	62.5	66.5	68.4	3.1
40	12	57.6	59.5	63.6	67.7	69.6	3.2
41	22	58.6	60.5	64.7	68.9	70.8	3.3
42	16	59.5	61.5	65.8	70.0	72.0	3.3
Total	535						

Table 7. Fitted 3rd, 10th, 50th, 90th and 97th centiles of foot length at 12 to 42 exact weeks of gestation, with number of fetuses for completed weeks of gestation.

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
12	3	5.9	6.8	8.9	10.9	11.8	1.6
13	3	8.5	9.6	11.7	13.9	14.9	1.7
14	7	11.3	12.3	14.6	16.9	18.0	1.8
15	7	14.0	15.2	17.6	20.0	21.2	1.9
16	12	16.8	18.0	20.6	23.2	24.4	2.0
17	16	19.6	20.9	23.6	26.3	27.6	2.1
18	11	22.4	23.7	26.6	29.5	30.8	2.2
19	16	25.2	26.6	29.6	32.6	34.0	2.3
20	15	28.0	29.5	32.6	35.8	37.2	2.5
21	21	30.8	32.3	35.6	38.9	40.4	2.6
22	18	33.5	35.1	38.6	42.0	43.6	2.7
23	18	36.2	37.9	41.5	45.0	46.7	2.8
24	22	38.9	40.7	44.4	48.0	49.8	2.9
25	17	41.5	43.3	47.2	51.0	52.8	3.0
26	20	44.1	46.0	50.0	53.9	55.8	3.1
27	22	46.6	48.6	52.7	56.8	58.7	3.2
28	20	49.1	51.1	55.3	59.6	61.6	3.3

(continued on next page)

Table 7 (continued)

Weeks of gestation	n	Fitted centiles					SD
		3rd	10th	50th	90th	97th	
29	20	51.4	53.5	57.9	62.3	64.3	3.4
30	18	53.7	55.8	60.4	64.9	67.0	3.5
31	24	55.9	58.1	62.8	67.4	69.6	3.6
32	22	58.0	60.3	65.1	69.9	72.1	3.8
33	19	60.0	62.3	67.3	72.2	74.5	3.9
34	11	61.9	64.3	69.4	74.5	76.8	4.0
35	15	63.7	66.1	71.4	76.6	79.0	4.1
36	16	65.4	67.9	73.3	78.6	81.1	4.2
37	11	66.9	69.5	75.0	80.5	83.1	4.3
38	12	68.4	71.0	76.7	82.3	85.0	4.4
39	6	69.7	72.4	78.2	84.0	86.7	4.5
40	10	70.9	73.7	79.6	85.5	88.3	4.6
41	10	71.9	74.8	80.8	86.9	89.7	4.7
42	8	72.8	75.7	81.9	88.1	91.0	4.8
Total	450						

superimposed. The estimated centiles for exact weeks of gestation are shown in Tables 1–7 together with the number of observations and fitted standard deviation. The regression equations are given in the Appendix.

The assumption of a normal distribution for each measurement at each gestational age was found to be reasonable.

Figure 8 compares our centiles for tibia and radius with those of two other studies. There is quite good agreement

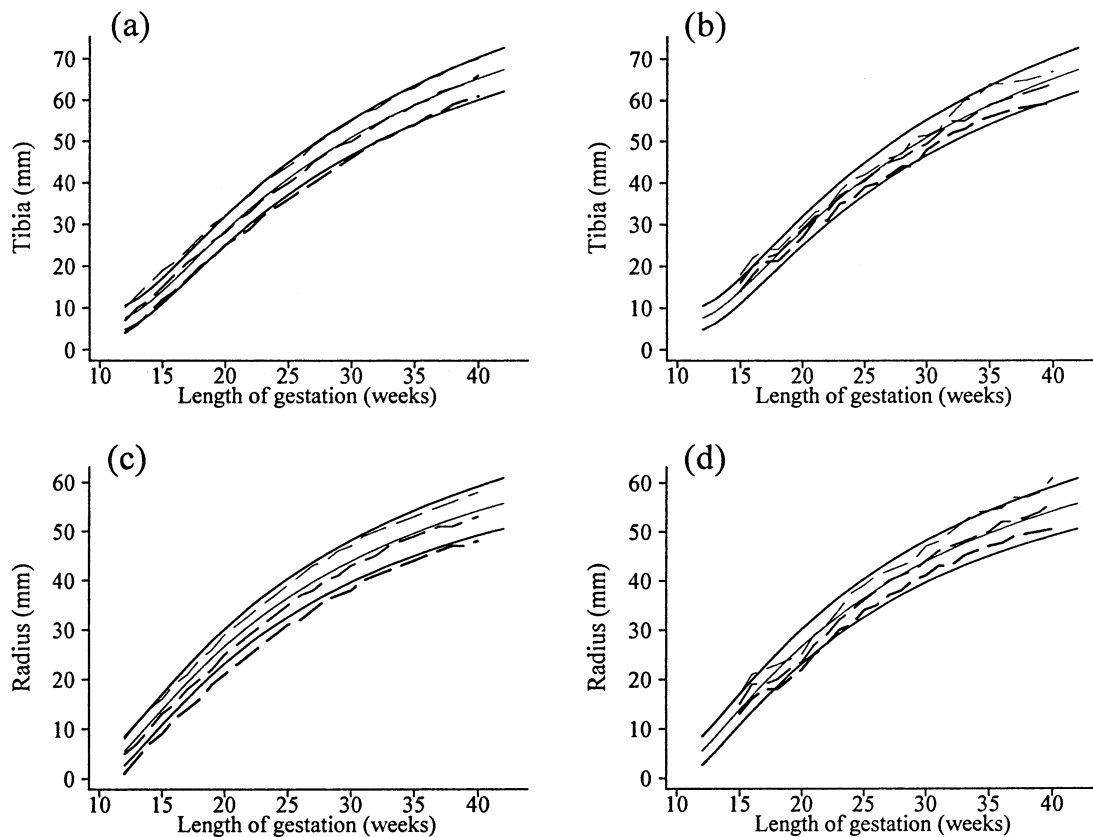


Fig. 8. Comparison of 5th, 50th and 95th centiles for tibia and radius obtained in this study (solid lines) with those of Merz *et al.*⁵ (panels a and c) and Exacoustos *et al.*⁶ (panels b and d) (short dashed lines). Also shown in panels (b) and (d) are the fitted curves of Exacoustos *et al.*⁶ (long dashed lines). The data of Merz *et al.*⁵ relate to completed weeks of gestation. Exacoustos *et al.*⁶ do not specify whether their centiles refer to exact or completed weeks of gestation.

with the centiles of Merz *et al.*⁵ but rather more discrepancy from the findings of Exacoustos *et al.*⁶, especially in early gestation. Their centiles are much closer together, although the medians are similar.

DISCUSSION

We have constructed new size charts for fetal long bone and foot length from 12 until 42 weeks of gestation. As with other measurements^{2,7-9}, we have shown the need to take into account the increasing variability of the measurements with increasing gestational age in the construction of the centiles. Our study was designed to overcome many of the methodological weaknesses that have been noted in many published fetal size centiles^{10,11}. In particular, fetuses were measured on only one occasion for the purposes of this study, all observations were collected prospectively and expressly for the development of centile charts, we excluded only two fetuses (for congenital abnormalities), we used statistical methods which give proper attention to the changing variability with increasing gestation and we carefully assessed the goodness of fit of the models obtained³.

Our charts of fetal size were derived from cross sectional data. They are appropriate for comparing the size of a fetus at a known gestational age with reference data. They are not suitable for judging the appropriateness of the growth of a fetus between two occasions³. Our centiles were derived from a population of western Europeans (75%) and Afro-Caribbeans (25%). The charts might not be entirely applicable to other ethnic groups.

We have compared our new charts with those of some other researchers using the radius and tibia as illustrative examples. Comparison with other studies is only possible if they present either means and outer centiles, or a full specification of a statistical model. Many studies fail to do so. Our centiles are quite close to those of Merz *et al.*⁵, who used a broadly similar approach to statistical analysis but did not give full detail of their sampling strategy. By contrast, our data are rather different from the centiles of Exacoustos *et al.*⁶, especially in early gestation. Those authors presented a model for the mean (see Fig. 8), but the outer centiles appear not to be derived from a statistical model. Both of these groups studied 'normal' pregnancies, but neither explained how their sample was selected.

In order to diagnose skeletal dysplasias as accurately as possible, it is necessary to compare the length of the bones with head and body size as well as determining the pattern of shortening (mesomelic, acromelic or rhizomelic). An advantage of our study is that all the measurements reported in this paper and our other papers^{8,9} were obtained on the same sample of fetuses, thus making comparison between the observed centiles of different body measurements more valid.

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Appendix. The regression equations used to generate the centiles in the figures and tables are as follows, where w is exact gestational age in weeks.

Humerus

Mean: $11.459w - 2.2362w \times \log(w) - 63.704$
SD: $0.040292w + 1.3464$

Radius

Mean: $7983/w^2 - 1698.6/w + 91.634$
SD: $0.046386w + 1.1933$

Ulna

Mean: $11120/w^2 - 2146.3/w + 108.94$
SD: $0.049218w + 1.2021$

Femur

Mean: $3.4162w - 0.0004791w^3 - 32.425$
SD: $0.058328w + 1.0605$

Tibia

Mean: $14451/w^2 - 2553.2/w + 120.05$
SD: $0.049978w + 1.1102$

Fibula

Mean: $13697/w^2 - 2458.0/w + 116.51$
SD: $0.053841w + 1.0451$

Foot

Mean: $0.36909w^2 - 0.084175w^2 \times \log(w) - 14.158$
SD: $0.10865w + 0.27971$

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