REFERENCE CHARTS OF FOETAL BIOMETRY IN ASIANS

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ABSTRACT

Objectives: To construct reference ranges for foetal biometry measurements of biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), humerus length (HL) and mandible length (ML) for the Asian population in Singapore.

Design: A prospective, cross-sectional study.

Setting: The obstetric ultrasound services and the labour ward of the department of Obstetrics and Gynaecology in Singapore General Hospital.

Subjects: The foetuses of 6,374 women whose delivery date was within 2 weeks of their estimated date of delivery (EDD) as calculated from the last menstrual period.

Method: During the period August 1, 1989 and December 31, 1993, 17,005 obstetric ultrasound scans were retrieved from the computerised database. These ultrasound scans were cross-referenced with the delivery database and the earliest ultrasound scan of 6,374 women who delivered within 2 weeks of their EDD were retrieved for analysis. Different growth models were fitted using regression analysis to estimate the mean and standard deviations as functions of gestational age. Centiles were then derived after confirming a normal distribution of measurements at each gestation.

Results: A total of 6,131 measurements of the BPD, 6,117 measurements of the HC, 6,017 measurements of the AC, 6,078 measurements of the FL, 2,863 measurements of the HL and 2,029 measurements of the ML were obtained. Regression analysis using the linear-cubic formula was used to model the mean values; a separate linear regression analysis was used to model the standard deviations.

Conclusion: These are the regressed reference charts from 6,374 Asian foetuses using parametric analysis of cross-sectional data. The authors encourage their use in Asian foetuses.

Keywords: ultrasound, antenatal, foetal sizes, biometry, Asian.

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INTRODUCTION

The need to construct intrauterine foetal biometry reference standards for our local population was emphasised in a previous paper comparing the BPD of Chinese foetuses with those of Caucasian foetuses[1]. The significant difference between the two populations could be due to a number of factors, difference in ultrasound machines used, methodological differences, demographic or socio-economic differences. This has been reemphasised in recent studies[2-5].

A recent study has shown that there were no significant racial differences in foetal biometry measurements of HC and AC of Chinese, Malay and Indian foetuses in our local population[6]. There was however, a statistically significant difference between the FL of the Indian foetuses and those of the Chinese and Malays. This statistical difference (mean 1.88mm, SD 0.94 mm) is however, unlikely to be translated into practical importance in clinical practice as it is within the limits of inter-observer variability[7]. Therefore, single reference standards of the various foetal measurements for the multi-racial Singapore population would be appropriate, simplifying its use in routine obstetric practice.

The construction of the charts of foetal sizes currently used in our department is described.

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METHODOLOGY

The majority of antenatal patients booked for delivery in Singapore General Hospital have a routine ultrasound scan done. The gestational age at booking period varies from as early as first trimester to as late as 41 weeks. Repeat ultrasound scans are performed for assessment of foetal growth, placental localisation and liquor volume estimation routinely at between 32 to 34 weeks gestation and when clinically indicated.

The ultrasound scans of all obstetric patients between August 1, 1989 and December 31, 1993 entered at the time of ultrasound scan into a computerised database were retrieved from analysis. Data entry errors were minimised by keying in the measurements at the time of the ultrasound scan. Transcription mistakes were corrected and re-keyed immediately after checking with all the measurements which were recorded on thermal paper. The printed report and graphs generated were checked again for gross errors.

After the neonate(s) was delivered, details of the mother and the neonate(s) were entered into a perinatal database located in the labour ward. This printed report of the daily delivery was cross-checked with the manual entry of patients into the labour ward delivery book and was filed for record purposes as well as for ease of retrieval of delivery statistics in the department.

There were 17,005 antenatal ultrasound records which were cross-referenced with the mother's unique identification number and last menstrual period in the 19,471 delivery records.

The following were excluded from the analysis:

(i) patients with multiple gestation,
(ii) patients whose last menstrual period (LMP) were unavailable,

(iii) patients whose delivery were induced,
(iv) patients who delivered by elective Caesarean section,
(v) patients who did not deliver within 2 weeks of estimated date of delivery,
(vi) Repeat measurements of the same foetus.

As a result of the above exclusion criteria, only the measurement of 6,374 foetuses were included in the final analysis. Ultrasound measurements were done on 3 ultrasound machines: one Aloka 280 and 2 Aloka 650s. All scans were performed using a curvilinear transducer. The machines were set to measure distance at a tissue speed of 1540 m/s. Measurements were done by 3 experienced ultrasonographers and 3 obstetricians in a standard manner described below.

Great pains were paid to adhering to ultrasound landmarks, as it has been shown that BPDs varying as much as 30% may be obtained with relatively similar views at the same examination time[8].

Biparietal diameter (BPD) and head circumference (HC)
Foetal head measurements were all made in the plane described by Campbell & Thoms[9]. This was the axial plane at the level where the continuous midline echo was broken by the cavum septum pellucidum in the anterior third. At this level, the anterior horns, the thalamus and posterior horns with the choroid plexus were visible. Measurements of the BPD were made from the proximal echo of the foetal skull to the distal side of the border deep to the ultrasound beam (outer to outer). The occipital-frontal diameter (OFD) was measured in the same plane between the leading edge of the frontal bone and the outer border of the occiput. The head circumference was then measured by using elliptical callipers superimposed over these 4 points. The machines calculation of an ellipse followed an approximate circle formula of HC = π (BPD+OFD)/2

Abdominal circumference (AC)
Abdominal circumference was measured on a transverse section through the foetal abdomen as described by Campbell & Wilkin[10]. This was at the level of the ductus venosus within the hepatic substance, in the anterior third of the foetal abdomen in the axial plane 90 degrees to the foetal spine and aorta posteriorly. The foetal stomach bubble is visible in the left of the section. As close to circular section as possible was obtained. Measured from skin to skin, the transverse and anterior-posterior diameters were first measured as the long or short axis of the ellipse and the circumference was obtained using elliptical callipers superimposed upon the 4 points.

Femur length (FL)
The full length of the femur was identified and in a plane as close as possible to right angles to the ultrasound beam. A straight measurement was made from the centre of one end of the diaphysis to the other, disregarding any curvature. In the third trimester care was taken not to include the distal femoral epiphysis[11].

Humerus length (HL)
This was similar to the measurement of the FL as described above. The humerus was identified by tracing it from the scapular spine located on the dorsal surface to the head of the humerus. The full length of the humerus was then obtained in a plane as close as possible to right angles to the ultrasound beam and the measurement was made from the centre of the ends of the bone.

Mandible length (ML)
This was obtained by moving the probe caudally from the plane of the head circumference until the temporal-mandibular joint came into view. The probe was then rotated obliquely toward the foetus while the temporal-mandibular joint was fixed in view. The length of the mandible was obtained by measuring the distance from the mandibular ramus adjacent to the temporal-mandibular joint to the mentum.

ANALYSIS AND RESULTS

Of the 6,374 records, a total of 6,131 measurements of the BPD, 6,117 measurements of the HC, 6,017 measurements of the AC, 6,078 measurements of the FL, 2,863 measurements of the HL and 2,029 measurements of the ML were used in the final analysis. These were analysed according to the parametric method described in detail by Altman & Chitty[2]. The number of measurements are not identical as not every foetus had every parameter measured every time and the humerus and mandible lengths were only added later in the ultrasound database.

In brief, for each ultrasound measurement polynomial regression models were fitted separately to the mean as functions of gestational age using SPSS for windows ver 6. In all cases, we found that the linear-cubic model gave an excellent fit to the mean. The goodness of fit of each regression model was carefully assessed by calculating the standard deviation scores (SDS) for each observation. This was obtained by subtracting the fitted mean from the observed value and dividing the difference by the fitted SD. The plot of standard deviation scores (standardised residuals) against the gestational age describing the mean with the 3rd and 97th centiles for BPD, HC, AC, FL, HL and ML showed no systematic over or under-estimation confirming a good fit of the scattergram to the proposed regression curve.

Centiles were derived on the assumption that at each gestational age the measurements had a normal distribution. For each measurement we produced a normal plot of the SDS and performed a Kolmogorov-Smirnov (Lilliefors) test of non-normality. The normal probability plots of BPD, HC, AC, FL, HL and ML confirm that the distributions at the various gestations are distributed normally.

The SD was modelled by the method described by Altman[12]. The residuals (differences between the observed values and the fitted mean) were converted into absolute residuals which were regressed on gestational age. This gave a standard deviation (SD) regression model that increased linearly with gestational age.

The summary measurements and fitted centile values for BPD, HC, AC, FL, HL and ML for each gestational week are shown in Tables I to VI.

DISCUSSION

Many authors have published charts (standards) of foetal size[13]. However, many of these studies which were flawed by weaknesses in design, statistical analysis or both, are still being used as local standards. Until recently, the working group of the British Medical Ultrasound Society (BMUS) had difficulty identifying even one study with appropriate methodology for some foetal measurements[13]. Recent studies[2-5] which have reported reference standards for foetal measurements have shown that there are differences between the new charts and the ones commonly used in the United Kingdom. As these 'older' charts are also still in use in Singapore, it is imperative that local and appropriately derived charts are used for our Asian population.

Table I - Summary measurements and fitted centiles of biparietal diameter

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
14	11	29.2727	1.9540	2.4	20.9	22.4	25.5	28.5	30.0
15	25	31.0800	2.0396	2.4	24.7	26.2	29.2	32.3	33.8
16	49	33.9388	3.1319	2.4	28.5	29.9	33.0	36.0	37.5
17	43	36.8140	3.4932	2.5	31.9	33.4	36.6	39.8	41.3
18	146	42.4589	3.0289	2.5	35.5	37.0	40.2	43.4	44.9
19	299	44.7893	2.6683	2.5	39.1	40.6	43.8	47.0	48.5
20	601	47.4809	3.0779	2.5	42.5	44.0	47.2	50.4	51.9
21	500	49.8220	2.9940	2.5	45.7	47.3	50.6	53.9	55.5
22	306	52.6830	3.3389	2.6	49.0	50.6	53.9	57.2	58.8
23	207	55.6039	3.6507	2.6	52.2	53.8	57.1	60.4	62.0
24	194	59.4175	4.4274	2.7	55.2	56.8	60.2	63.7	65.3
25	169	62.7278	3.6018	2.7	58.2	59.8	63.3	66.7	68.3
26	169	65.7456	4.1390	2.7	61.1	62.7	66.2	69.7	71.3
27	163	69.1472	4.1309	2.7	64.0	65.6	69.0	72.5	74.1
28	195	72.1282	4.0979	2.8	66.5	68.2	71.8	75.3	77.0
29	192	74.8594	3.7102	2.8	69.1	70.8	74.4	78.0	79.6
30	240	77.2417	4.0654	2.8	71.6	73.3	76.9	80.5	82.1
31	278	79.8633	3.7690	2.8	74.0	75.7	79.3	82.8	84.5
32	325	82.1446	3.5470	2.9	76.1	77.8	81.5	85.2	87.0
33	367	84.2044	3.6656	2.9	78.2	80.0	83.7	87.4	89.1
34	437	85.9908	3.7928	2.9	80.2	82.0	85.7	89.4	91.1
35	381	87.9160	3.8097	2.9	82.1	83.9	87.6	91.3	93.0
36	324	88.6728	4.0121	3.0	83.7	85.5	89.3	93.2	95.0
37	265	90.6340	3.5630	3.0	85.3	87.1	90.9	94.8	96.6
38	165	91.7091	3.2291	3.0	86.7	88.5	92.4	96.2	98.0
39	63	92.3016	3.3823	3.1	87.9	89.7	93.7	97.7	99.5
40	11	93.0909	4.5045	3.1	89.0	90.9	94.9	98.8	101
41	6	91.3333	2.5820	3.1	90.0	91.9	95.9	99.8	102
	Total 6,131								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-31.506820 + 4.195880w - 0.000648w^3$
SD = $2.017434 + 0.026620w$

Fig 1 – Comparison of our BPD measurements with those of Chitty et al (outer-outer)

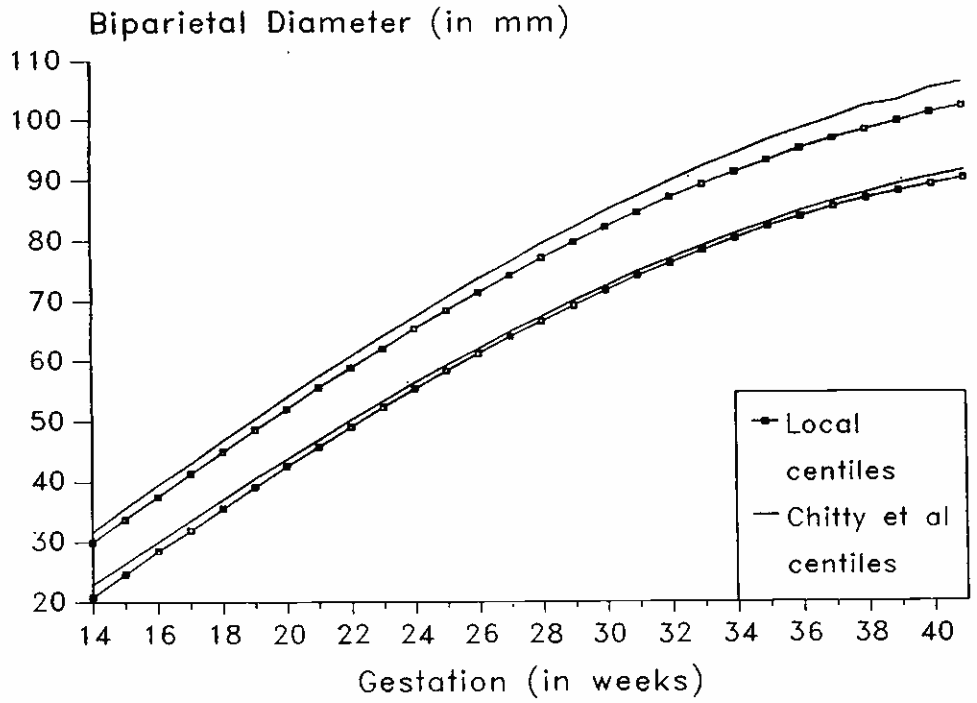

Table II - Summary measurements and fitted centiles of head circumference

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
14	6	103.83	10.53	8.9	69.1	74.4	85.8	97.2	103
15	21	106.81	7.85	8.9	83.3	88.6	100	111	117
16	46	117.04	10.28	8.9	97.2	103	114	125	131
17	41	128.17	11.97	9.0	111	116	128	139	144
18	147	148.98	10.83	9.0	124	129	141	152	158
19	300	157.77	9.70	9.0	137	142	154	166	171
20	600	167.97	10.87	9.0	150	155	167	178	184
21	500	176.97	10.43	9.0	162	168	179	191	196
22	306	187.40	11.66	9.0	174	180	191	203	208
23	207	198.83	11.77	9.1	186	191	203	214	220
24	194	211.91	13.74	9.1	197	202	214	226	231
25	169	223.10	12.37	9.1	208	213	225	237	242
26	168	233.94	13.29	9.1	218	224	235	247	253
27	163	245.33	12.95	9.1	228	234	245	257	263
28	195	256.59	12.96	9.1	238	243	255	267	272
29	192	266.73	12.58	9.2	247	252	264	276	281
30	240	274.56	13.41	9.2	255	261	273	284	290
31	278	282.21	13.05	9.2	263	269	281	292	298
32	324	290.34	11.41	9.2	271	276	288	300	306
33	368	296.08	15.53	9.2	278	283	295	307	313
34	436	302.75	11.27	9.2	284	290	302	313	319
35	381	307.92	11.51	9.3	290	296	308	319	325
36	322	311.10	11.01	9.3	295	301	313	325	330
37	266	317.55	10.86	9.3	300	306	318	329	335
38	165	320.42	9.87	9.3	304	310	322	333	339
39	65	323.55	9.87	9.3	307	313	325	337	342
40	11	325.55	12.01	9.4	310	316	328	340	345
41	6	319.00	9.96	9.4	312	318	330	342	347
	Total 6,117								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-129.735590 + 15.951564w - 0.002822w^3$
SD = $8.653468 + 0.017436w$

Fig 2 – Comparison of our HC measurements with those of Chitty et al (outer-outer)

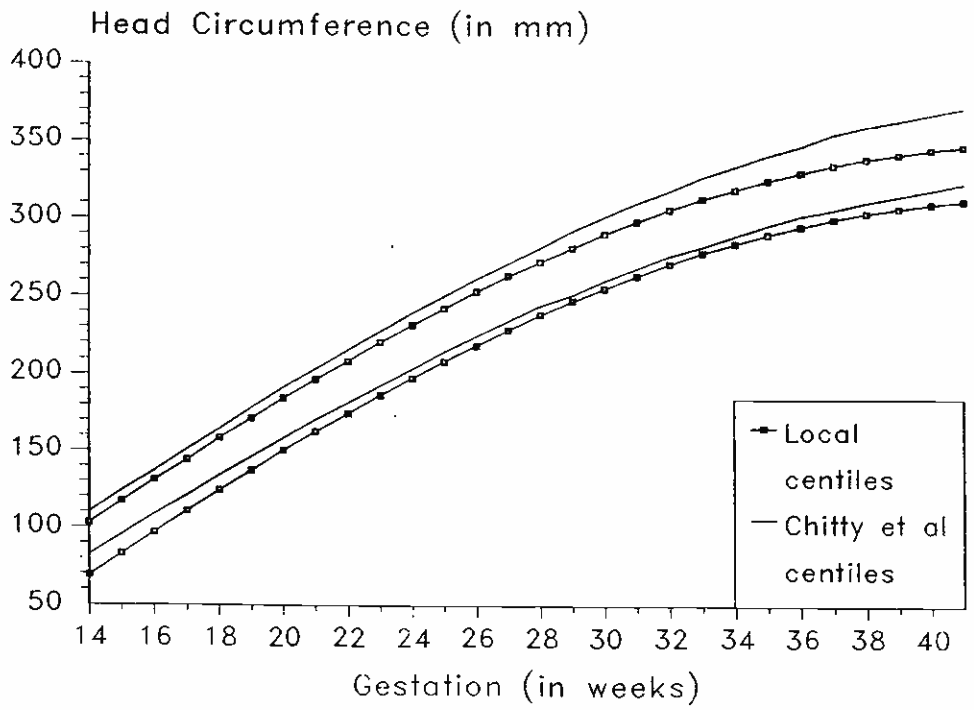

Table III - Summary measurements and fitted centiles of abdominal circumference

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
15	2	98.50	7.78	6.9	74.2	78.3	87.2	96.0	100
16	14	102.93	7.10	7.2	85.3	89.7	98.9	108	112
17	17	111.65	10.79	7.5	96.4	101	110	120	125
18	133	128.03	11.04	7.8	107	112	122	132	137
19	297	136.46	9.90	8.0	118	123	133	144	148
20	601	146.04	10.79	8.3	129	134	145	155	160
21	500	154.21	10.82	8.6	140	145	156	167	172
22	306	164.00	12.48	8.9	150	155	167	178	184
23	207	173.44	11.50	9.2	160	166	178	189	195
24	194	186.36	15.06	9.5	170	176	188	201	206
25	168	197.14	12.56	9.7	181	187	199	211	217
26	169	205.54	13.30	10	191	197	209	222	228
27	161	218.54	12.54	10	201	207	220	232	238
28	195	230.18	14.77	11	209	216	230	244	250
29	192	239.56	14.39	11	219	225	239	254	260
30	240	249.43	14.59	11	228	235	249	263	270
31	277	260.51	14.15	11	238	245	259	273	279
32	325	269.39	14.63	12	245	253	268	283	290
33	369	278.65	15.14	12	254	262	277	292	300
34	435	287.09	15.73	12	263	270	286	301	308
35	381	296.33	16.59	13	270	278	294	311	319
36	322	301.59	15.58	13	278	286	303	320	327
37	266	311.08	18.36	13	287	294	311	328	335
38	164	314.96	16.11	13	295	302	319	336	343
39	65	322.45	14.46	14	300	309	327	345	353
40	11	324.91	21.43	14	308	316	334	352	360
41	6	323.17	14.05	14	315	323	341	359	368
	Total 6,017								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-96.727764 + 12.502069w - 0.001082w^3$
SD = $2.701234 + 0.281248w$

Fig 3 - Comparison of our abdominal circumferences (AC) measurements with those of Chitty et al.

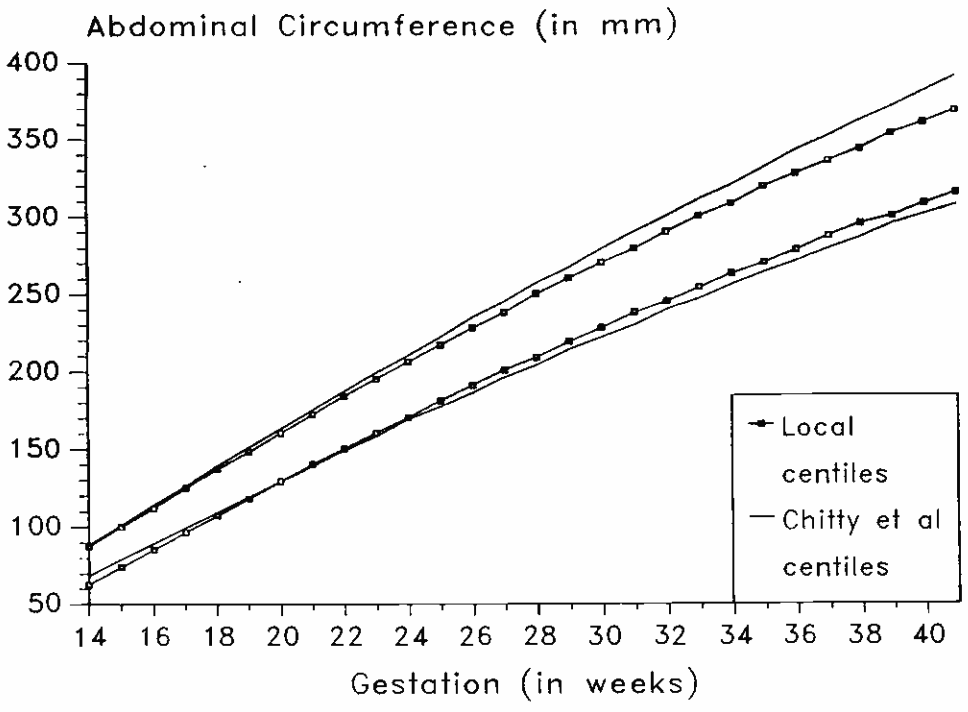

Table IV - Summary measurements and fitted centiles of femur length

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
14	3	17.67	1.53	1.9	9.5	10.6	13.1	15.5	16.6
15	15	17.60	1.30	1.9	12.5	13.6	16.1	18.5	19.6
16	34	19.50	2.14	1.9	15.4	16.6	19.0	21.4	22.6
17	37	21.24	2.48	2.0	18.2	19.4	21.9	24.5	25.7
18	144	26.06	2.99	2.0	21.0	22.2	24.8	27.4	28.6
19	298	28.17	2.55	2.0	23.9	25.1	27.6	30.2	31.4
20	601	30.66	2.62	2.0	26.6	27.9	30.4	33.0	34.2
21	499	32.74	2.51	2.1	29.2	30.5	33.1	35.8	37.1
22	305	35.26	2.81	2.1	31.9	33.1	35.8	38.5	39.8
23	207	37.76	2.63	2.1	34.5	35.7	38.4	41.1	42.4
24	194	40.65	3.17	2.1	37.0	38.3	41.0	43.7	44.9
25	168	43.48	2.92	2.2	39.3	40.7	43.5	46.3	47.6
26	169	45.49	3.05	2.2	41.8	43.1	45.9	48.7	50.0
27	160	48.28	3.13	2.2	44.1	45.4	48.2	51.1	52.4
28	194	50.54	2.91	2.2	46.4	47.7	50.5	53.4	54.7
29	192	52.93	3.38	2.3	48.4	49.8	52.8	55.7	57.1
30	240	54.98	3.14	2.3	50.6	51.9	54.9	57.8	59.2
31	278	57.38	2.85	2.3	52.6	54.0	57.0	59.9	61.3
32	325	59.03	3.08	2.3	54.6	56.0	58.9	61.9	63.2
33	368	60.98	3.10	2.4	56.3	57.7	60.8	63.9	65.3
34	435	62.80	3.08	2.4	58.1	59.6	62.6	65.7	67.1
35	381	64.59	3.04	2.4	59.8	61.3	64.3	67.4	68.9
36	321	65.53	2.95	2.4	61.5	62.9	66.0	69.0	70.5
37	265	67.57	3.08	2.5	62.8	64.3	67.5	70.7	72.2
38	163	68.63	3.12	2.5	64.2	65.7	68.9	72.1	73.6
39	65	69.57	2.63	2.5	65.6	67.1	70.3	73.5	75.0
40	11	70.55	3.01	2.5	66.8	68.3	71.5	74.7	76.2
41	6	70.83	2.23	2.6	67.8	69.3	72.6	76.0	77.5
	Total 6,078								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-31.616122 + 3.275868w - 0.000436w^3$
SD = $1.529900 + 0.025382w$

Fig 4 – Comparison of our femur length (FL) measurements with those of Chitty et al

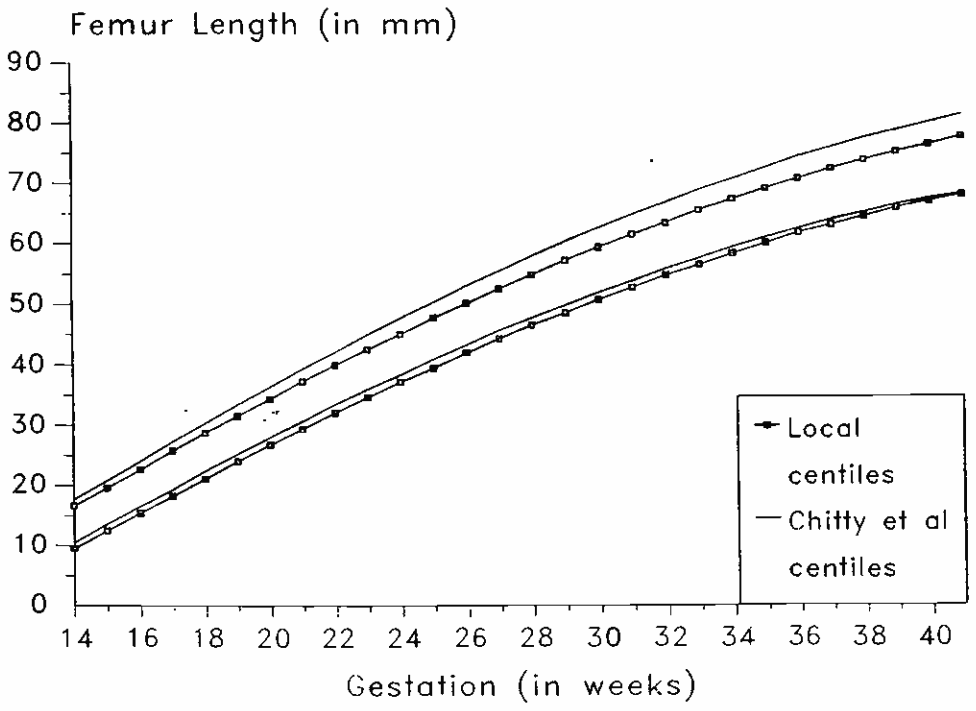

Table V - Summary measurements and fitted centiles of humerus length

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
16	5	19.00	2.45	1.8	15.9	16.9	19.2	21.5	22.6
17	6	22.67	1.86	1.8	18.3	19.3	21.6	24.0	25.0
18	44	25.11	2.30	1.9	20.4	21.6	24.0	26.4	27.6
19	120	26.40	2.84	1.9	22.8	23.9	26.3	28.8	29.9
20	252	28.68	2.47	1.9	25.0	26.2	28.6	31.0	32.2
21	264	30.53	2.81	2.0	27.1	28.3	30.8	33.4	34.6
22	161	32.94	3.19	2.0	29.2	30.4	33.0	35.6	36.8
23	117	35.34	2.39	2.0	31.4	32.6	35.1	37.7	38.9
24	76	37.03	3.13	2.1	33.2	34.5	37.2	39.9	41.1
25	69	39.14	2.90	2.1	35.3	36.5	39.2	41.9	43.1
26	92	40.96	3.04	2.2	37.0	38.3	41.1	44.0	45.3
27	77	43.21	2.76	2.2	38.9	40.2	43.0	45.8	47.2
28	100	45.42	3.08	2.2	40.7	42.0	44.8	47.6	49.0
29	74	46.62	2.56	2.3	42.3	43.6	46.6	49.5	50.9
30	128	47.84	3.66	2.3	43.9	45.3	48.2	51.2	52.6
31	132	49.86	3.25	2.3	45.5	46.9	49.9	52.8	54.2
32	167	51.34	3.30	2.4	46.9	48.3	51.4	54.4	55.9
33	191	52.81	3.02	2.4	48.3	49.7	52.8	55.9	57.3
34	214	54.21	3.10	2.5	49.5	51.0	54.2	57.4	58.9
35	200	55.70	2.82	2.5	50.8	52.3	55.5	58.7	60.2
36	160	56.34	3.16	2.5	52.0	53.4	56.6	59.9	61.3
37	110	57.59	3.88	2.6	52.9	54.4	57.8	61.1	62.6
38	66	59.18	3.17	2.6	53.9	55.4	58.8	62.1	63.7
39	30	58.87	2.70	2.6	54.8	56.4	59.7	63.0	64.6
40	4	58.75	3.30	2.7	55.4	57.1	60.5	64.0	65.6
41	4	63.00	2.94	2.7	56.2	57.8	61.2	64.7	66.3
	Total 2,863								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-22.974217 + 2.743170w - 0.000410w^3$
SD = $1.195913 + 0.037114w$

The exclusion criteria in this study were similar to those in Chitty et al[2-4]. For example, the previous studies excluded patients with uncertain last menstrual period and patients with multiple pregnancies and foetuses with foetal abnormalities. It was also crucial to include only one measurement at a particular gestational age per foetus in the construction of reference standards to avoid the inter-dependence of multiple measurements on the same foetus[14]. In our study, the first ultrasound for each foetus was used to construct the reference standards. As our patients booked for delivery at different gestational ages during pregnancy, the various gestations at which the ultrasound scan done was entirely random and reflected the pattern of booking. Furthermore, only women who delivered within 2 weeks of their EDD were included in this study. This contrasts to the studies by Chitty & Altman[3-5] where the foetuses born prematurely were included. This was evidenced by their need to further recruit women after 36 weeks as some of these randomly allocated had already delivered. We believe that our strict criteria of excluding foetuses who delivered prematurely, either spontaneously or as a result of intervention, is important in view of the association between prematurity and intra-uterine growth retardation[15].

The larger the sample size, the greater the precision the resulting centiles will have. Because the attention is concentrated on the tails of the distribution (the extreme values), several hundred observations are necessary to get reasonable estimates of extreme centiles[12]. The sample size used here is by far the largest of the reference standards published. Ultrasound data for reference standards should either be collected cross-sectionally or longitudinally, but not a mixture of the two. Centiles derived from longitudinal or serial measurements from each foetus are limited by the fact that serial measurements on an individual foetus are highly correlated and interdependent. The use of regression analysis in the analysis of longitudinal data is inappropriate and will result in an underestimation of the residual variance[14]. Hence the need for cross-sectional data as used here. The centiles change smoothly across gestation and the scatter diagram data with the fitted centiles superimposed show appropriate modelling confirming the departure from linearity towards term. The goodness of fit is confirmed in the plots of standardised residuals against gestational age which show no systematic error. The normal probability plots confirm that the data are a reasonable sample from a normal distribution.

Comparison of the appropriate 'newer' charts with ours (Fig 1 to 4) demonstrate differences, which are not explained by differences in the study design and methods of data analysis. We conclude, therefore, that there are inherent differences between Asian and Caucasian foetuses.

Growth is about change in foetal size[16] and correct reference standards need to be used for the appropriate population.

CONCLUSIONS

This study contains the largest sample size among the

Table VI - Summary measurements and fitted centiles of mandible length

Weeks of gestation	Number of foetuses	Mean (mm)	SD	Regressed SD	Fitted Centiles				
					3rd	10th	50th	90th	97th
16	4	18.25	0.50	2.0	11.7	12.9	15.5	18.0	19.2
17	4	19.25	1.71	2.0	13.2	14.4	17.0	19.5	20.7
18	32	19.44	1.98	2.1	14.5	15.7	18.4	21.1	22.4
19	92	20.83	2.48	2.1	15.9	17.2	19.9	22.6	23.8
20	202	21.63	2.22	2.2	17.1	18.5	21.3	24.1	25.4
21	215	22.49	2.22	2.2	18.5	19.8	22.6	25.5	26.8
22	132	23.92	2.37	2.3	19.7	21.0	24.0	26.9	28.3
23	99	25.34	2.93	2.3	21.0	22.3	25.3	28.2	29.6
24	68	26.28	2.96	2.4	22.0	23.5	26.5	29.6	31.1
25	64	28.00	3.05	2.4	23.2	24.7	27.8	30.8	32.3
26	70	29.61	3.34	2.4	24.4	25.9	28.9	32.0	33.4
27	63	30.19	3.53	2.5	25.4	26.9	30.1	33.3	34.8
28	76	31.57	3.50	2.5	26.4	27.9	31.1	34.4	35.8
29	51	32.71	3.25	2.6	27.3	28.9	32.2	35.5	37.1
30	88	33.28	3.81	2.6	28.3	29.9	33.2	36.5	38.1
31	94	34.12	3.37	2.7	29.0	30.7	34.1	37.6	39.2
32	115	34.81	3.29	2.7	29.9	31.6	35.0	38.5	40.1
33	120	35.22	3.15	2.8	30.6	32.3	35.8	39.4	41.1
34	125	36.96	3.94	2.8	31.4	33.0	36.6	40.2	41.9
35	118	37.58	3.83	2.9	31.9	33.6	37.3	41.1	42.8
36	81	38.02	3.64	2.9	32.5	34.3	38.0	41.7	43.5
37	66	38.64	3.17	3.0	33.0	34.8	38.6	42.4	44.2
38	28	38.96	3.26	3.0	33.5	35.3	39.1	43.0	44.8
39	18	39.89	2.22	3.1	33.8	35.6	39.6	43.6	45.4
40	2	39.50	0.71	3.1	34.2	36.0	40.0	44.0	45.8
41	2	40.00	2.83	3.2	34.3	36.3	40.4	44.4	46.4
	Total 2,029								

SD = Standard deviation
Regression equation, where w is the gestational age in weeks:
Mean = $-10.999138 + 1.726507w - 0.000282w^3$
SD = $1.170202 + 0.049214w$

published charts of uniform reference standard for foetal sizes. It is the first to contain the regressed equations used to generate the charts amongst the 3 Asian races in Singapore. Similar reference charts derived from smaller sample sizes by the authors have been in use in our department since 1989. Our overall perinatal mortality rate was 5.86 per 1,000 births for the past 7 years (1987 - 1993). The main cause of our perinatal mortality have been congenital malformations which account for about 45% of all neonatal deaths. Asphyxia and asphyxia-related conditions account for only 18% of neonatal deaths.

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REFERENCES

1. WB Chan, GSH Yeo. A comparison of foetal biparietal diameter measurements between local Chinese and Caucasian populations. Singapore Med J 1991; 32: 214-7.
2. Altman DG, Chitty LS. Charts of foetal size: Methodology. Br J Obstet Gynaecol 1994a; 101: 29-34.
3. Chitty LS, Altman DG, Henderson A, Campbell S. Charts of foetal size. Head measurements. Br J Obstet Gynaecol 1994b; 101: 35-43.
4. Chitty LS, Altman DG, Henderson A, Campbell S. Charts of foetal size: 3, Abdominal measurements. Br J Obstet Gynaecol 1994c; 101: 125-31.
5. Chitty LS, Altman DG, Henderson, A, Campbell S. Charts of foetal size: 4 Femur length. Br J Obstet Gynaecol 1994d; 101: 132-5.
6. GSH Yeo, WB Chan, KC Lun, FM Lai. Racial differences in foetal morphometry in Singapore. Ann Acad Med Singapore 1994; 23: 371-6.
7. Chang TC, Robson SC, Spencer JA, Gallivan S. Ultrasonic foetal weight estimation: analysis of inter- and intra-observer variability. J Clin Ultrasound 1993; 21: 515-9.
8. Shepard M, Fily RA. A standardized plane for biparietal diameter measurement. J Ultrasound Med 1982; 1: 145-50.
9. Campbell S, Thoms A. Ultrasound measurement of the foetal head to abdominal circumference ratio in the assessment of growth retardation. Br J Obstet Gynaecol 1977; 84: 165-74.
10. Campbell S, Wilkin D. Ultrasonic measurement of foetal abdominal circumference in the estimation of foetal weight. Br J Obstet Gynecol 1975; 82: 689-97.
11. Warda AH, Deter RL, Rossavik IK, Carpenter RJ, Hadlock FP. Foetal femur length: a critical reevaluation of the relationship to menstrual age. Obstet Gynae 1985; 66: 69-75.

12. Altman DG. Construction of age-related reference centiles using absolute residuals. Stat Med 1993; 12; 917-24.
13. British Medical Ultrasound Society Foetal Measurements Working Party. Clinical applications of ultrasonic foetal measurements. London: British Institute of Radiology, 1990.
14. Deter RL, Harrist RB, Hadlock FP, Poindexter AN. Longitudinal studies of foetal growth with use of dynamic image ultrasonography. Am J Obstet Gynecol 1982; 143: 545-54.
15. Tamura RK, Sabbagha RE, Depp R, Varisrub N, Dooley SL, Socol ML. Diminished growth in foetuses born preterm after spontaneous labour or rupture of membranes. Am J Obstet Gynecol 1984; 148: 1105-10.
16. Altman DG, Hytten FE. Intrauterine growth retardation. Let's be clear about it. Br J Obstet Gynaecol 1989; 96: 1127-8.