Original Research Article

Gestational age assessment in newborns using regression equation of anthropometric parameters singly or in combination

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Abstract

Aim: To find the best parameter for gestational age (GA) assessment by calculating regression equation of the best anthropometric parameter alone and/or in combinations in rural parts of India.

Setting & design: This was a cross sectional prospective study conducted at the department of Pediatrics, NIMS Medical College & Hospital, Jaipur, Rajasthan during September 2012 to October 2013 with sample size of 1000 patients. All the cases of singleton newborns between the GA of 28 to 43 weeks were included in study.

Materials and method: After considering all inclusion criteria all the subjects were examined within 72 hours of birth by a single observer using predefined methods. Birth weight (BW), Foot Length (FL), Head Circumference (HC) and crown-heel length of each case were measured and the mean, standard deviation, 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 97th percentiles were calculated. Regression equations of GA incompleted weeks and weeks plus days (nearest week) with all anthropometric parameters were calculated.

Result: In the present study all the four anthropometric measurements highly correlated well with GA in completed weeks as well as with weeks plus days (nearest week)and were found to be highly statistically significant(p<0.0001). Amongst anthropometric parameters individually, FL, had maximum positive correltaion(r=0.878) with GA in completed weeks followed by BW(r=0.799), HC(r=0.766) and crown to heel length (r=0.764) respectively.

Conclusion: The overall best correlation for prediction of GA, alone and in combination is found by combined parameters (BW, FL, HC &crown to heel length). The best individual anthropometric parameters for GA assessment is foot length.

Keywords: Anthropometric parameters, head circumference, foot length, birth weight, Rural population.

1. Introduction

Fetal growth is dependent on genetic, placental and maternal factors. Morbidity and mortality in newborns is directly correlated with gestational age and weight. An estimated 1 million babies die globally every year because of prematurity, of which about 375,000 neonatal deaths due to prematurity and low birth weight occur in India alone.[1,2] Early neonatal deaths contributing to an estimation of 64% infant deaths.[3] Till date there is no method available to serve as a gold standard for assessment of accurate gestational age. Gestational age can be assessed by last menstrual period (Naegele's formula) or by ultrasonic or growth charts evaluation during pregnancy and after birth using New Ballard Score. Each of these methods has their own advantages and limitations.

Gestational age assessment is done by recording gestation duration in completed weeks since the 1st day of Last menstrual period. Last menstrual period is reliable only if the menstrual cycles are regular and not associated with use of hormonal contraceptives or maternal diseases.[4] Evidences show that there is difference of at least two weeks between gestational and conceptional age. There are lots of studies available in which LMP criteria were used in completed weeks as a measure to assess gestational age. Which of these is better cannot be surmised. Recording of birth weight presents a major logistic problem at rural community level due to lack of basic facilities such as electronic weighing machine and infantometer while measuring tape is easily available everywhere, is cost

effective and does not require expertise in measurement. The main purpose of this study is to design a method for the assessment of gestational age, which can be easily done at any primary health care center with very basic facilities and very basic health care personnel without the expertise of a pediatrician or neonatologist required for assessment of gestational age by complicated physical and/or neurological criteria like modified Ushers, Dubowitz, Ballard's and New Ballard Criteria.

1.2 Aims and objectives

To find simple tool for assessment of gestational age in rural settings by using regression equation of anthropometric parameters (birth weight, head circumference, crown to heel length, foot length). To find the best parameter amongst birth weight, crown to heel length, foot length and head circumference alone or in combination.

2. Materials and Methods

This Cross sectional prospective study was conducted from September 2012 to October 2013 in a rural tertiary care teaching hospital. The study was approved by the Institutional Ethical Committee and written consent for participating neonates was taken from their parents/guardians. One thousand randomly selected singleton newborns between the gestational ages of 28 to 43 weeks were included and formed the study group.

Exclusion criteria consisted of mothers not knowing LMP exactly, Multiple pregnancy, New born with gross congenital anomalies, Chronic maternal disease - severe hypertension, diabetes mellitus, cardiac disease and severe anemia, TORCH infections positive mothers, Obstetrical complications known to compromise fetal growth – eclampsia, History of smoking, alcohol consumption or drug abuse.

All the subjects were examined within 72 hours of birth by a single observer and assessment of gestational age was done as per LMP by Naegele's formula, i.e. addition of 9 months and 7 days to the first day of LMP and by Extended New Ballard Score. Birth weight in kilograms and foot length, head circumference and crown heel length of each case were measured in centimeters.

Methods of measurements were as per "Handbook of physical measures" by Hall JG *et al*.[5] These babies were then tabulated according to their gestational age, weight and sex. Using Microsoft Excel spread sheet the mean, standard deviation, 5th, 10th, 50th, 90th, and 95th percentiles were calculated to establish a

regression equations. Measurements of foot length, head circumference, crown to heel length and birth weight were done and correlated with last menstrual period. The correlation of foot length with gestational age was analysed by applying correlation and regression analysis. Regression equation was derived to predict gestational age from foot length head circumference, crown to heel length and birth weight or in combination of all four parameters.

3. Results

Out Of the 1000 subjects studied, 452 (45.2%) were females and 548 (54.8%) were males. Their distribution with respect to GA is graphically represented in Fig 1. The proportion of cases in each gestational week (28 to 43) was not evenly divided. The largest section was formed by the 38 weeks (18.9%) while the extremes accounted for the smallest portions, namely 1.4% by 29, 1.5% 30 and 1.9 % 28 , 2.1% 42 weeks and 0.3% by 43 weeks.

Predicted gestational age in weeks plus days (nearest week) (r = 0.898, P < 0.001) showed highly significant Pearson correlation by combined parameters (foot length, birth weight, crown to heel length) with actual gestational age in weeks plus days (nearest week).

In the present study all the four anthropometric measurements highly correlated well with gestational age in weeks plus days (nearest week) and were found to be highly statistically significant (p<0.0001). Amongst anthropometric parameters individually, foot length, had maximum positive correltaion (r = 0.878) with gestational age in completed weeks followed by birth weight (r = 0.799), head circumference (r =0.766) and crown to heel length (r = 0.764) respectively.

Actual gestational age in weeks plus days(nearest week) significantly correlated most with predicted geastational agein weeks plus days (nearest week) by combined parameters (foot length , birth weight, crown to heel length) (r = 0.898) followed by foot length (r = 0.875) , birth weight (r = 0.798), head circumference (r = 0.765) and crown to heel length (r = 0.762) respectively. Individually, foot length, hadbest correltaion with gestational age in completed weeks as well as in weeks plus days (nearest week), whereas in combination best correlations was found with combined parameters (foot length, birth weight, crown to heel length) in weeks plus days (nearest week) followed by foot length, birth weight and crown to heel length in order.

Figure 1: Break-up of the study sample in each gestational age
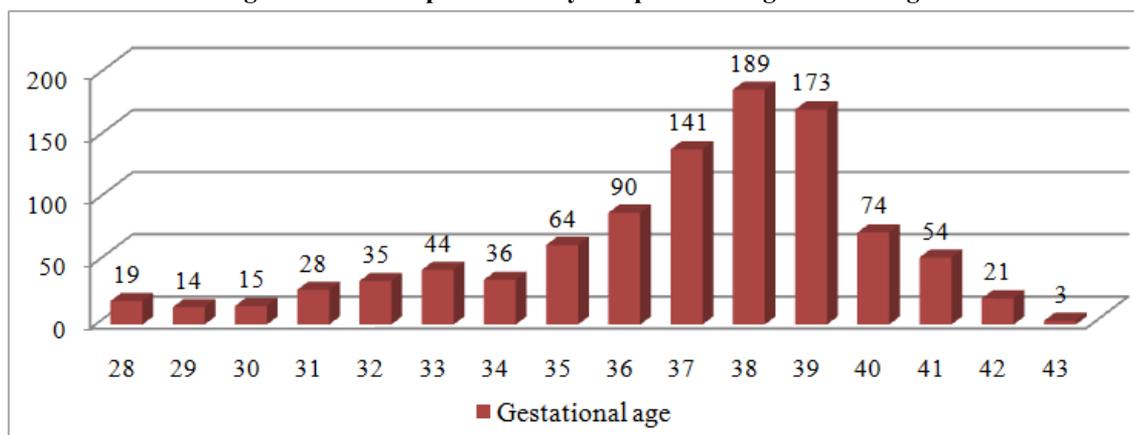
Outline of the number of babies present in each gestational age group and the mean, standard deviation and percentiles of their various anthropometric parameters are presented in the tables no 1 below.

Table 1: (Mean, standard deviation and percentiles for birth weights (kgms)

GA	N	Mean	SD	Mean-2SD	Mean+2SD	Percentile								
						3rd	5th	10th	25th	50th	75th	90th	95th	97th
28	19	0.9	0.09	0.73	1.07	0.8	0.8	0.8	0.83	0.89	0.97	1	1.1	1.1
29	14	1.02	0.19	0.64	1.4	0.8	0.8	0.82	0.88	0.98	1.11	1.37	1.54	1.54
30	15	1.31	0.38	0.55	2.07	0.92	0.92	1.03	1.14	1.25	1.3	1.92	2.61	2.61
31	28	1.46	0.13	1.21	1.72	1.29	1.29	1.3	1.37	1.47	1.56	1.61	1.75	1.8
32	35	1.51	0.13	1.24	1.78	1.25	1.25	1.29	1.41	1.51	1.6	1.69	1.71	1.75
33	44	1.7	0.27	1.16	2.24	1.18	1.22	1.42	1.5	1.64	1.89	2.15	2.2	2.2
34	36	1.77	0.44	0.89	2.64	1.02	1.02	1.11	1.5	1.95	2.08	2.3	2.45	2.45
35	64	1.97	0.35	1.27	2.67	1.28	1.31	1.5	1.71	2	2.22	2.43	2.45	2.6
36	90	2.31	0.48	1.36	3.26	1.02	1.2	1.8	2.09	2.4	2.68	2.85	2.95	3
37	141	2.65	0.37	1.9	3.4	1.8	2.1	2.2	2.5	2.7	2.8	3	3.47	3.57
38	189	2.79	0.32	2.15	3.43	2.2	2.2	2.37	2.56	2.84	3	3.2	3.28	3.4
39	173	2.81	0.46	1.9	3.73	1.85	2.1	2.3	2.5	2.78	3.1	3.3	3.75	3.85
40	74	3.1	0.47	2.16	4.03	2.45	2.49	2.5	2.64	3	3.6	3.73	3.75	3.94
41	54	3.01	0.44	2.12	3.9	2.32	2.36	2.4	2.63	3.02	3.25	3.56	3.86	4.14
42	22	2.8	0.37	2.06	3.54	2.4	2.4	2.4	2.5	2.64	3.21	3.37	3.49	3.5
43	2	3.51	0.13	3.26	3.76	3.42	3.42	3.42	3.42	3.51	3.6	3.6	3.6	3.6

Table 2: (Mean, standard deviation and percentiles for foot lengths in centimetres)

GA	N	Mean	SD	Mean-2SD	Mean+2SD	Percentile								
						3rd	5th	10th	25th	50th	75th	90th	95th	97th
28	19	5.57	0.11	5.36	5.78	5.3	5.3	5.4	5.5	5.6	5.6	5.7	5.7	5.7
29	14	5.84	0.31	5.21	6.46	5.5	5.5	5.5	5.6	5.8	6.03	6.45	6.5	6.5
30	15	5.97	0.17	5.63	6.3	5.5	5.5	5.68	5.9	6	6	6.2	6.2	6.2
31	28	6.21	0.15	5.91	6.52	5.8	5.89	6	6.1	6.2	6.3	6.41	6.5	6.5
32	35	6.35	0.28	5.78	6.92	5.5	5.5	6.06	6.3	6.4	6.5	6.54	6.7	7.06
33	44	6.53	0.25	6.02	7.04	6.07	6.2	6.2	6.33	6.5	6.7	6.8	7.1	7.27
34	36	6.75	0.46	5.83	7.68	6.02	6.17	6.2	6.45	6.7	6.8	7.42	8	8
35	64	7.02	0.34	6.35	7.69	6.5	6.5	6.6	6.8	7	7.1	7.25	7.95	8
36	90	7.21	0.63	5.94	8.47	5.87	6	6.3	7	7.2	7.5	7.98	8.5	8.5
37	141	7.58	0.4	6.77	8.39	7.03	7.2	7.2	7.4	7.6	7.7	8	8.18	8.87
38	189	7.69	0.23	7.23	8.15	7	7.25	7.5	7.6	7.7	7.8	8	8	8.13
39	173	7.8	0.23	7.34	8.25	7.4	7.5	7.6	7.7	7.8	7.9	8	8.13	8.2
40	74	8.03	0.17	7.69	8.38	7.7	7.7	7.8	7.9	8	8.2	8.2	8.33	8.4
41	54	8.07	0.23	7.61	8.54	7.5	7.65	7.8	8	8.1	8.2	8.3	8.4	8.61
42	22	8.25	0.19	7.88	8.63	7.8	7.82	7.93	8.2	8.3	8.4	8.47	8.5	8.5
43	2	8.5	0	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5

Table 3: (Mean, standard deviation and percentiles for head circumference in centimetres)

GA	N	Mean	SD	Mean-2SD	Mean+2SD	Percentile								
						3rd	5th	10th	25th	50th	75th	90th	95th	97th
28	19	25.19	1.33	22.53	27.85	22.6	22.6	22.8	24.8	25.1	26	27.3	27.5	27.5
29	14	26	3.56	18.87	33.13	23	23	23.1	23.75	24.8	26.95	33.6	35.7	35.7
30	15	26.93	1.38	24.16	29.69	24.4	24.4	24.46	26.4	26.7	27.7	29.08	29.2	29.2
31	28	28.63	1.31	26.01	31.24	27	27	27.09	27.8	28.35	29.2	30.22	31.83	33
32	35	28.59	1.53	25.52	31.65	26.05	26.48	26.6	27.3	28.6	29.5	31.12	31.5	31.5
33	44	29.43	1.54	26.34	32.52	25.81	26.2	26.6	28.6	29.5	30.5	31.5	31.5	31.57
34	36	30.13	2.24	25.64	34.62	26.5	26.5	26.5	29.03	30.5	31.6	32	32.75	36.45
35	64	30.44	1.7	27.05	33.84	25.9	26	29	29.6	30.75	31.6	32.1	32.6	33.05
36	90	31.47	2.14	27.19	35.75	25.5	26.5	28	31	32	33	33	34.5	34.5
37	141	32.76	1.74	29.27	36.25	29.5	30.5	31.02	32	32.9	33.6	35	35.59	35.8
38	189	33.39	1.26	30.88	35.9	30.6	31.09	32	32.5	33.5	34.1	35	35.5	35.5
39	173	33.24	1.44	30.35	36.12	30.53	31	31.28	32.5	33.4	34.1	35	35.5	36.5
40	74	33.85	1.2	31.45	36.25	32	32	32.5	33	33.85	34.5	35.55	35.98	36.5
41	54	33.97	1.32	31.33	36.61	30.98	31.5	31.95	33.08	34	34.65	35.8	36.25	36.44
42	22	33.85	1.89	30.07	37.64	26.5	27.48	33	33.35	34	34.85	35.76	36.43	36.5
43	2	34.1	0.14	33.82	34.38	34	34	34	34	34.1	34.2	34.2	34.2	34.2

Table 4: (Mean, standard deviation and percentiles for CHL (Crown to heel length) in centimetres)

GA	N	Mean	SD	Mean-2SD	Mean+2SD	Percentile								
						3rd	5th	10th	25th	50th	75th	90th	95th	97th
28	19	36.76	2.43	31.9	41.61	34.5	34.5	34.7	35	36	38.2	39	44.9	44.9
29	14	35.41	1.66	32.1	38.73	32.8	32.8	32.95	34.05	35.45	36.93	37.75	38.3	38.3
30	15	38.8	2.1	34.59	43.01	35.4	35.4	35.52	37.5	39.2	40.9	41.46	42	42
31	28	40.68	1.51	37.66	43.69	35.9	37.48	39.4	39.85	40.75	41.5	43.02	43.53	43.8
32	35	41.63	2.09	37.45	45.81	39	39	39.3	40.5	41.5	42.5	43	46.34	50.08
33	44	41.77	2.86	36.04	47.49	36	36.25	37.75	41	42	43	43.8	44.4	50.9
34	36	42.67	4.04	34.6	50.74	34	34	34	41.5	42.75	45	46.9	49.15	49.89
35	64	44.31	2.54	39.23	49.4	40	40	41	42.63	44.5	46	48	48	48.1
36	90	44.75	3.16	38.44	51.06	37	37.55	40	43.1	45	47.6	48.2	49	49
37	141	46.52	2.68	41.16	51.87	42	42	43.2	45	46.4	48.05	49.5	50.5	51.3
38	189	47.73	2.51	42.72	52.75	42	43	45	46.9	48	49	51	52	52
39	173	48.2	2.09	44.03	52.37	44	44.5	45	47	48.3	49.9	50.84	52	52
40	74	49.47	2.35	44.77	54.18	45.05	45.2	46.8	47.9	49.5	51.2	52.2	53.8	55
41	54	48.81	2.13	44.55	53.07	43.63	43.93	46	47.65	48.95	50.25	51.3	52.35	53.44
42	22	48.85	1.86	45.12	52.57	46	46.05	46.51	47.38	48.4	50.13	51.91	52	52
43	2	50.8	0.28	50.23	51.37	50.6	50.6	50.6	50.6	50.8	51	51	51	51

Table 5: Correlation co-efficients (r) and regression equation between actual gestational age (weeks plus days) and other anthropometric parameters

Parameters	Correlation co-efficient	Co-efficient of determination (r^2)	Regression equation#
Birth weight (kg.)	0.798	0.637	Y = 24.852X + 198.511
Head circumference	0.765	0.586	Y = 6.136X + 63.136
Crown to heel Length	0.762	0.581	Y = 3.994X + 76.008
Foot Length	0.875	0.765	Y = 26.263X + 65.37
HC (X_1)+FL (X_2)+ BW (X_3)+L (X_4)	0.898	0.806	Y = 18.052X_2+ 6.572X_3+0.767X_4+74.657

#Based on y = mx + b, where y is the gestational age to be calculated, x is the available parameter and m & b are constants

It is evident from above table No.5 that co-efficients of determination (r^2 = 0.806) was maximum when all anthropometric parameters except head circumference was entered in regression model. It was immediately followed by foot length (r^2 = 0.765), birth weight (r^2 =0.637), head circumference (r^2 = 0.586) and length (r^2 = 0.581).

4. Discussion

As most of the older studies and all those conducted in India relied on LMP as the main criteria and on early sonographic measurements in majority of the subjects. We chose LMP as our main criteria and in light of the paucity of early sonographic measurements in majority of subjects , we chose LMP if definitely known

as our main criteria, though we did apply the clinical scoring by new ballard score, which was done by other observer and blinded.

WHO recommends the reporting of gestational age in completed weeks.[6] Again it can be seen that most of the older studies used nearest weeks as criteria for assigning gestational age. In light of the above observations we used the standard WHO criteria of completed weeks for LMP as a standard part of inclusion and also recorded the LMP in exact days, so as to be able to compare with our own and with other studies more accurately. By this method we should also be able to see which of these two criteria correlate better with our assessment of gestational age, by new ballard criteria, as well as by my derived regression equation using various anthropometric parameters singly and/or in combination, blinded and done by two observers. Our values of birth weight are similar to those by Laxminarayan *et al* [7] from Madras, Singh *et al*[8] from Delhi and Balakrishnan *et al*[9] from Pondicherry. However the match is seen close to the values of Singhal *et al*[10] and Gandhi *et al*[11], Thawani *et al*[12], Amita M[13], Purohit A[14] in the present study. The apparent reason being that the demographic profile of the population studied was the similar except the more cases are local rural, thus suggesting that the variation in the results from other studies is more on the basis of regional variation rather than statistical error. The values of crown to heel length correlated well with the gestational age in completed weeks at a value of (r = 0.764), which is comparable to study of Singhal *et al*[10] (r = 0.9 29), Narendra *et al*[15] (r= 0.726) and Bhatia *et al*[16] (r = 0.643).

Singhal *et al*[10] having maximum correlation with present study, which could be due to similarities in characteristics of sample. Though Singhal *et al*[10] also found foot length as best criteria (r = 0.934) as compare to present study amongst the single parameters but Singhal *et al*[10] did not incorporate combined parameters.

There is no study till date to the best of knowledge, which has compared or correlated with gestational age in completed weeks and days (nearest week) with the anthropometric parameters and New Ballard Criteria. This is the only study so that it can comparable with any study.

In the present study the regression equations were also calculated in exact days and found that maximum correlation was seen with combine parameters followed by foot length, birth weight, head circumference and crown to heel length. As in other similar studies these calculations are based on completed weeks as parameter and not in exact days, so it is not possible to compare the results of this study with others in terms of exact days due to non-availability, though like these studies present study has

studied these parameters in completed weeks so they are comparable.

5. Conclusion

The overall best correlation for prediction of gestational age, alone and in combination, is found by combined parameters (foot length, crown to heel length, birth weight). The best individual anthropometric parameters for GA assessment is foot length.

The best anthropometric parameters for prediction of gestational age in combination is calculated by combined parameters (foot length, crown to heel length, birth weight).The method used in this study is quick, can be easily done at any primary health care centre with very basic facilities and basic health care personnel with the help of ordinary measuring tape without the expertise of a pediatrician or neonatologist. The importance of this method is in the fact that basic health care personnel can identify the high risk cases easily and can quickly refer them for further management to higher centre, if required, where expert health care facilities are available.

Limitations of the study

The major limitation of this study is the small size of the sample population (1000) which when divided for each gestational age further reduces the sample size at the extremes i.e., 28, 29 and 43 weeks. This may account for the skewing which is most notable at these gestational ages.

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