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Simple empirical formulae for expressing the lineal growth of the human fetus.

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In the quantitative study of the growth of the human body there is often need for simple and accurate formulæ for expressing the relation between body-length and prenatal age. Empirical formulæ for lineal growth in the fetal period (3 lunar months to birth) have been published by Hassee[1], Henry and Bastien[2], and Scammorn[3]. No one of these is entirely satisfactory, for the first gives results which are not in accord with modern findings regarding prenatal lineal growth, the second is highly complicated, and the third is primarily for use in estimating the length from the age, whereas one usually desires to determine the age from the length. Practicable formulæ of this kind should fulfill the following conditions: (a) They should express age in terms of body-length for the entire fetal period (3 months to birth). (b) They should give a close fit to reliable data on the subject. (c) They should be in simple form, which will permit their application with ordinary arithmetic without the use of tables of special functions and the like. With these conditions in mind the following formulæ have been developed on the basis of the data of Mall[4].

When Mall's observations are placed in graphic form they approximate a parabola having the general form: $T = a + bL + cL^2$, where T is the age in fetal or lunar months (calculated from the first day of the last menstruation), L is the total or crown-heel length in cm., and a, b and c are constants. The specific formula for expressing this relations is:

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1 Hasse, *Charité Ann.*, 1875, ii, 669.

2 Henry et Bastien, *C. R. Acad. Sc.*, 1904, cxxxix, 811.

3 Scammon, PROC. SOC. EXP. BIOL. AND MED., 1921, xix, 133.

4 Mall, Determination of the age of human embryos and fetuses; Keibel and Mall, *Human Embryology*, 1910, i, 199.

$$(1) \quad T = 2.3 + \frac{2.5 \ L}{28} + \frac{L^2}{784}.$$

This may be simplified to:

$$(2) \quad T = (\frac{L}{28} + 1.25)^2 + 0.74.$$

For estimating the crown-heel length from the age, the formula may be transformed into:

$$L = 28\sqrt{T - 0.74} - 35.$$

These formulæ may also be modified for further use. According to Mall, the cohabitation age averages 10 days less than the menstrual age which is estimated from the first day of the last menstruation, and the individual deviations from this average are quite small. Therefore, the formula for menstrual age may be modified to

$$(3) \quad T = 1.94 + \frac{2.5 \ L}{28} + \frac{L^2}{784}$$

or

$$(4) \quad (\frac{L}{28} + 1.25)^2 + 0.38$$

to express the cohabitation age.

While the above formulæ are not complicated, somewhat simpler ones may be used for approximate values. These are

$$(5) \quad T = (-\frac{L}{30} + 1.49)^2$$

for estimating age from total length and

$$(6) \quad L = 30\sqrt{T} - 44.7$$

for estimating length from age.

The values given by these various formulæ and their absolute and percentage deviations from Mall's observed values are shown in the accompanying tables.

TABLE I.

Observed and Calculated Body-length of the Human Fetus by Fetal Months.

Age in fetal months	Total body-length by interpolation from Mall's data (a)	Total body-length calculated by exact formula (b)	Total body-length calculated by approximate formula (c)	Deviation of "b" from "a" cm.	Per cent.	Deviation of "c" from "a" cm.	Per cent.
3	7.06	7.08	7.26	+0.02	+0.28	+0.20	+2.97
4	15.55	15.54	15.30	—0.01	—0.07	—0.25	—1.67
5	22.53	22.79	22.38	+0.26	+1.15	—0.15	—0.66
6	29.40	29.20	28.79	—0.20	—0.68	—0.61	—2.01
7	35.00	35.05	34.67	+0.05	+0.14	—0.33	—0.94
8	40.83	40.43	40.15	—0.40	—0.98	—0.68	—1.42
9	45.40	45.47	45.20	+0.07	+0.15	—0.20	—0.49
10	50.00	50.20	50.17	+0.20	+0.40	+0.17	+0.34
			Sum	1.21	3.85	2.59	10.50
			Mean	0.15	0.48	0.32	1.31

TABLE II.

Observed and Calculated Age of the Fetus at 5 cm. Intervals of Body-length.

Total (crown-heel) body-length (cm.)	Age in fetal months by interpolation from Mall's data (a)	Age in fetal months as calculated by exact formula (b)	Age in fetal months as calculated by approximate formula (c)	Deviation of "b" from "a" Fetal months	Per cent.	Deviation of "c" from "a" Fetal months	Per cent.
5	2.71	2.78	2.72	+0.07	+2.58	+0.01	+0.36
10	3.38	3.32	3.29	—0.06	—1.77	—0.09	—2.66
15	3.92	3.93	3.96	+0.01	+0.25	+0.04	+1.02
20	4.605	4.61	4.62	+0.005	+0.10	+0.015	+0.32
25	5.36	5.35	5.38	—0.01	—0.18	+0.02	+0.37
30	6.08	6.03	6.20	—0.05	—0.82	+0.12	+1.97
35	6.95	6.99	7.02	+0.04	+0.57	+0.07	+1.01
40	7.82	7.90	7.95	+0.08	+1.02	+0.13	+1.66
45	8.905	8.90	8.99	—0.005	—0.05	+0.85	+0.95
50	10.00	9.95	9.93	—0.05	—0.50	—0.07	—0.70
Sum				0.38	7.84	0.65	11.02
Mean				0.038	0.78	0.065	1.10