An Attempt to Standardize the Calculation of Growth Velocity of Preterm Infants—Evaluation of Practical Bedside Methods

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Objective To examine how well growth velocity recommendations for preterm infants fit with current growth references: Fenton 2013, Olsen 2010, INTERGROWTH 2015, and the World Health Organization Growth Standard 2006.

Study design The Average (2-point), Exponential (2-point), Early (1-point) method weight-gains were calculated for 1,4,8,12, and 16-week time-periods. Growth references' weekly velocities (g/kg/d, gram/day and cm/week) were illustrated graphically with frequently-quoted 15 g/kg/d, 10-30 grams/day and 1 cm/week rates superimposed. The 15 g/kg/d and 1 cm/week growth velocity rates were calculated from 24-50 weeks, superimposed on the Fenton and Olsen preterm growth charts.

Results The Average and Exponential g/kg/d estimates showed close agreement for all ages (range 5.0-18.9 g/kg/d), while the Early method yielded values as high as 41 g/kg/d. All 3 preterm growth references were similar to 15 g/kg/d rate at 34 weeks, but rates were higher prior and lower at older ages. For gram/day, the growth references changed from 10 to 30 grams/day for 24-33 weeks. Head growth rates generally fit the 1 cm/week velocity for 23-30 weeks, and length growth rates fit for 37-40 weeks. The calculated g/kg/d curves deviated from the growth charts, first downward, then steeply crossed the median curves near term.

Conclusions Human growth is not constant through gestation and early infancy. The frequently-quoted 15 g/kg/d, 10-30 gram/day and 1 cm/week only fit current growth references for limited time periods. Rates of 15-20 g/kg/d (calculated using average or exponential methods) are a reasonable goal for infants 23-36 weeks, but not beyond. *(J Pediatr 2017;■■:■■-■■).*

See editorial, p •••

Neonatologists, neonatal dietitians and nurses monitor hospitalized preterm infants' growth based on daily weight, and weekly length and head circumference measurements. Clinicians often use target growth velocities of 15 g/kg/d[1-4] or 10-30 grams/day[5] for weight gain and 1 cm/week for head and length gain[4] to evaluate infants' nutritional status. However, expert advisory groups[6-8] have not specified grams and centimeter per week growth goals, but rather recommend that preterm infants grow and accrete nutrients similar to the fetus.[6-8]

Fenton et al recently reported on the variability of methods used to evaluate preterm infant growth velocity. In this systematic review of 373 studies, growth velocities were reported in g/kg/d (40%), g/d (32%), and changes in z-scores (29%).[9] Most of the authors did not report the kg denominator that was used to calculate the g/kg/d, but among those reporting their calculations, a variety of methods were used (**Table I**).[9] It is not known if differences in these daily growth targets and methods of calculating growth velocities yield different patterns of preterm growth over time and how well these patterns fit with current reference growth curves (Fenton 2013, Olsen 2010, INTERGROWTH 2015, and WHOGS 2006[10-14]). Furthermore, as others have noted,[15] these variations in calculation methods make comparisons between studies difficult and meta-analysis of study results unreliable.[15]

Our goal for this study was to examine how well the frequently-quoted growth velocity recommendations (15 g/kg/d, 10-30 grams/day and 1 cm/week) fit with current growth references. To accomplish this, we first compared 3 methods to calculate g/kg/d for weight (the Avg2pt, Exp2pt, and Early1pt methods).[9] Then we calculated the weekly growth velocity of the 4 reference growth curves[10-14] and graphed these, superimposed over the frequently-quoted growth velocity recommendations[1-4,16] Finally, to illustrate the effects of using 15 g/kg/d and 1 cm/week cumulatively, these were calculated from 24 to 50 weeks and superimposed on the Fenton and Olsen growth chart curves.

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Table I. Weight gain calculation methods over a period of time

Early 1-point method (Early1pt)	$(W_2 - W_1) / (W_1/1000) /$ number of days
Exponential 2-point method (Exp2pt)	$1000 \times \ln (W_2/W_1) /$ number of days
Average 2-point average method (Avg2pt)	$(W_2 - W_1) / [(W_2 + W_1)/2] /1000 /$ number of days

W_1 and W_2 are initial and final body weight expressed in grams.

Methods

To evaluate potential differences in the three methods used to calculate growth velocity, the medians from the Fenton 2013 growth chart (average combined) were used to calculate weight gain over 5 time frames (1, 4, 8, 12, and 16-weeks) using each of the three frequently cited weight gain calculation methods (Avg2pt, Exp2pt and Early1pt methods) (**Table I**).[9] The differences between the 3 calculation methods were expressed as percentages [(method A – method B) / method B] (**Table II**).

Using 4 growth references,[10-14] growth velocity rates were calculated weekly from 22-50 postmenstrual weeks and illustrated graphically for weight using g/kg/d (Avg2pt (**Figure 1**, A), Exp2pt (**Figure 1**, B), and gram/day (**Figure 1**, C), and for head circumference and length using cm/week (**Figure 1**, D and E). Male and female data median curves were averaged together for these calculations. The four growth references were the Olson 2010 curves,[11] the Fenton 2013 curves,[10] the 2015 INTERGROWTH-21 curves,[12] and a term infant growth standard (WHOGS 2006).[13,14] For the WHOGS, we used the expanded tables that illustrate postnatal weight loss.[14]

These dynamic growth velocities were then compared with the frequently-quoted fixed growth velocities of 15 g/kg/d and 10-30 grams/day for weight and 1 cm/week[4] for length and head circumference. This was done by superimposing the fixed growth velocities over the curves generated using the four reference curves (**Figure 1**, A-E).

Table II. Differences in weight gain calculation results according to the calculation method and time frame, using the Fenton 2013 growth chart median curve

Period for calculation (wk)	Post menstrual age (weeks)	Average 2-point method	Exponential 2-point method	Early 1-point method	Exponential 2-point method vs Average 2-point method	Early 1-point method vs Average 2-point method	Early 1-point method vs Exponential 2-point method
1 week	23 to 24	18.1	18.1	19.3	0.13%	6.8%	6.6%
1 week	24 to 25	18.9	18.9	20.2	0.15%	7.1%	6.9%
1 week	25 to 26	18.4	18.4	19.7	0.14%	6.9%	6.7%
1 week	26 to 27	17.9	17.9	19.1	0.13%	6.7%	6.5%
1 week	27 to 28	17.7	17.8	18.9	0.13%	6.6%	6.5%
1 week	28 to 29	17.8	17.8	19.0	0.13%	6.6%	6.5%
1 week	29 to 30	18.0	18.0	19.2	0.13%	6.7%	6.6%
1 week	30 to 31	18.2	18.2	19.4	0.14%	6.8%	6.7%
1 week	31 to 32	18.0	18.0	19.2	0.13%	6.7%	6.6%
1 week	32 to 33	17.2	17.2	18.3	0.12%	6.4%	6.3%
1 week	33 to 34	16.0	16.0	17.0	0.11%	5.9%	5.8%
1 week	34 to 35	14.7	14.7	15.5	0.09%	5.4%	5.3%
1 week	35 to 36	13.2	13.3	13.9	0.07%	4.9%	4.8%
1 week	36 to 37	11.7	11.7	12.2	0.06%	4.3%	4.2%
1 week	37 to 38	10.1	10.1	10.5	0.04%	3.7%	3.6%
1 week	38 to 39	8.8	8.8	9.1	0.03%	3.2%	3.1%
1 week	39 to 40	8.1	8.1	8.3	0.03%	2.9%	2.9%
1 week	40 to 41	7.9	7.9	8.1	0.03%	2.8%	2.8%
1 week	41 to 42	7.9	7.9	8.1	0.03%	2.9%	2.8%
1 week	42 to 43	7.8	7.8	8.0	0.02%	2.8%	2.8%
1 week	43 to 44	7.5	7.5	7.7	0.02%	2.7%	2.7%
1 week	44 to 45	7.1	7.1	7.3	0.02%	2.6%	2.5%
1 week	45 to 46	6.7	6.7	6.9	0.02%	2.4%	2.4%
1 week	46 to 47	6.2	6.2	6.4	0.02%	2.2%	2.2%
1 week	47 to 48	5.8	5.8	5.9	0.01%	2.1%	2.1%
1 week	48 to 49	5.4	5.4	5.5	0.01%	1.9%	1.9%
1 week	49 to 50	5.0	5.0	5.1	0.01%	1.8%	1.8%
4 weeks	24 to 28	17.9	18.3	23.8	2.2%	33%	31%
4 weeks	28 to 32	17.6	18.0	23.4	2.1%	33%	30%
4 weeks	32 to 36	15.1	15.3	19.1	1.5%	27%	25%
4 weeks	36 to 40	9.6	9.7	11.1	0.6%	16%	15%
4 weeks	40 to 44	7.8	7.8	8.7	0.4%	12%	12%
4 weeks	44 to 48	6.5	6.5	7.1	0.3%	10%	10%
8 weeks	28 to 36	15.5	16.7	28	7%	77%	65%
12 weeks	24 to 36	12.8	14.3	28	12%	117%	94%
12 weeks	28 to 40	14.7	17.2	39	17%	162%	124%
16 weeks	24 to 40	12.4	15.3	41	23%	228%	166%

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