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The In Utero and in the Postnatal Period Growth in Human Newborns

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Abstract

We made an analysis of several published curves concerning the human fetal and postnatal growth assessed by the three classical parameters including their velocity changes: the body weight, the length and the head circumference. The called fetal curves have a diagnostic purpose on the normality of growth during the fetal life. They derived from measurements go from 25 to 42 weeks. Among these diagnostic charts, the best from a mathematical and statistical points of views is the one of publishes by "Dombrowski". Several other analyzed fetal curves may be criticized for not meeting all the criteria of a statistical normal population, mainly concerning the body weight. The called combined fetal and postnatal curves go from 25 to 60 weeks. They allow to make an appreciation of the normal of postnatal growth; they take into account the interruption of fetal life and the adaptation of growth for the priority of growth follows a different vector in this type of situations. Among these combined charts, the "Gairdner" and "Battisti" meet the criteria for all parameters. The analysis of velocity (their variability over time) of the different parameters of growth considered individually or as ratios between them has also been useful. The clinician having in care fragile neonates (those born before 30 weeks or below 1000g or those combining a prematurity and a fetal growth restriction) has an important task. It is to offer the best nutrition to them and to see if their growth is optimal as this can be important for the future. The clinician needs hence to plot longitudinally, on an appropriate curve , the three parameters of growth (body weight, length and head circumference). That should be done on a combined chart instead diagnostic curve. On the other hand, a reliable ratio emerged has a highly correlated index to optimal growth, and it can be used from 25 to 60 weeks of post-conceptional age (PCA) :

d BW g/d HC cm = 44 PCA – 1138 ($r = 0.973$, $p < 0.00001$). By using that formula derived by two important and easy parameters (the body weight and the head circumference), on can appreciate the adequacy of growth whatever the considered moment in that period of life.

Keywords: Fetal growth; Prematurity; Nutrition; Postnatal growth

Introduction

Growth in general, and even more when it concerns a fragile neonate or child, is an important and constant aspect of care for the family and for the medical staff [1-9]. Growth is made of different dimensions, not having the same priority at a given time [1-16]. A compromised growth during special periods can be associated or followed by an abnormal development [4,12-37]. The most frequently used parameters for assessing growth are:

i. the body weight and length, the circumferences of head and (left) arm, the skin folds; these are ***the absolute indices*** ;

ii. there are also ***the relative indices*** such as the ponderal index, the body mass or Quetelet's index: they are the ratios among different parameters. These indices have the purpose to assess the harmony of growth.

iii. ***the velocity indices*** have the purpose to assess the variability over a period of time of a given parameter, and hence to appreciate the influence of nutritional or endocrine factors.

The present work makes the analysis of the different growth charts concerning the fetal, neonatal and postneonatal periods. It aims to bring to the clinician pragmatic tools to appreciate the adequacy of nutrition and the longitudinal growth of the most fragile newborns: those born before 30 weeks, those having a body weight below 1000 g, those combining a prematurity and retarded intrauterine growth. For these situations are being questionable at least during the hospital period till 60 weeks post conceptional age or PCA [12-37]. Concerning these populations, the simple questions « which curve, what parameters of growth should be chosen?» may become complex (35b).

Population, Methods and Statistics

The growth charts

It is not possible to retain all the till now published charts. Some are even updated owing different social and demographic factors [18,27-56]. One has to make the following ***classification between the curves***.

1. In the real fetal curves, measurements are done during intra-uterine life by ultrasounds methods [12,41,50,56].

2. In so called fetal or diagnostic curves , measurements are done as soon as possible at birth in babies born at differents gestational ages, these being gathered in progression of gestational age classes:«Lubchenco», «Usher-Mclean», «Babson» and «Dombrowski» curves are some examples of these.

3. In the combined charts, the populations are comprising the same babies measured at birth and also during their postnatal period extended to 60 weeks post conceptional age:«Dunn», «Gairdner», «Cope» et«Battisti» curves are representative of these.

The classical longitudinal curves starting at term after a normal fetal life are not valuable owing to the intervention of prematurity [4,6,7]. The combined charts take into account:

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- The spontaneous evolution following the already in utero began growth's trajectoire,
- The «placental fatigue» normally observed at the end of a normal pregnancy: this phenomenon is actually explained by the placental fibrosis and the relative restrained intrauterine space or volume. This last aspect explains the flattened shape of curves observed at the end of fetal life.

That «natural fetal programme» is then relayed by the baby own neuroendocrine mechanisms allowing him or her to be followed by the definitve line expressed by centiles or standard deviations of mean values, and usually observed at 4-6 months after term [4,6,7,9].

In the postnatal curves, growth is evaluated in a longitudinal way: that is by plotting during time the consecutive increments of the different dimensions, most often during the hospital stay [10,19,27,34,44,50,51], either for singletons, or twins or even triplets, or taking into account a special starting point such as a body weight < 1000g or a gestational age < 30 weeks. Most complete data are however being found in "Babson", "Battisti", "Dombrowski", "Gairdner", "Lubchenco" and "Usher-Mclean" works. For that reason, those charts have thoroughly been analysed.

Considered items in the analysis are: the statistical normality of the population, the body weight and length, the head circumference, the arm circumference, the weekly gains in those parameters in dividing the babies' lives in multiple periods, also the relative gains (obtained ratios) in weight over length or over head circumference, the mathematical correlations of the different indices with gestational ages.

The statistical calculation: of data providing the results of median, mean and mode values, the results of (simple and multiple) regression coefficients and of variations coefficients, and the sample volume for population follows the appropriate recommendations [57,58].

Results

Analysis of normality of populations presented in the different works

All the described curves have a sufficient sample to reach the statistical significance.

A population can be considered as normal from a statistical point of view if median = mean = mode. Moreover, the coefficient of variation of a given parameter has to be comprised between 4 and 18 %.

In Table 1, one can find for the different parameters in every populations the coefficients of variation (CV in %), which is the ratio of the standard deviation over the mean times 100. The CV is given for each parameter: body weight (BW), length (BL) and head circumference (HC). As far as BW is concerned, one can see that normality of population is not found for «Lubchenco» and «Usher-Mclean». Those for «Gairdner» are limit. The greatest variations are found in «Lubchenco».

- Among the so called fetal (and hence diagnostic) curves, the best one from a statistical point of view is «Dombrowski».
- Among the combined curves, both are equivalent for the 3 considered parameters, and the values reach the statistical requirements.

Analysis of the correlations between the different parameters of growth and the gestational age

The mathematical analysis of data in different curves is obviously fastidious. However, that gives the possibility to build up the formulas with the correlation (r) and determination (r2) coefficients between the different parameters of growth and the gestational age given in Table 2 [57,58]. These coefficients have elevated values (0.98 à 0.99), traducing a very high association force between the parameters and the PCA.

The original data and curves can be found in the respective references.

Author(s), year(s)	Intervals in weeks , parameters	CV : BW	CV : BL	CV : HC
Babson, 1970,1976	26-42 ; 26-92 ; BW,BL,HC	14	8	9
Battisti, 1992	25-60 ; BW,BL,HC,PI	13	7	6
Dombrowski	1992, 26-42 ; BW,BL,HC	13	5.3	4
Gairdner 1971	26-60 ; BW,BL,HC	17	4.4	4
Lubchenco 1966, 1970	26-42 ; BW,BL,HC, PI	22	11	10
Usher-McLean 1969	25-44 ; BW,BL,HC	26	8	6

Table 1: Analysis of the coefficients of variation (CV) for the 3 parameters of growth: body weight (BW), length (BL).

Author	PCA and BW	PCA and BL	PCA and HC
Babson *	BW= 176 PCA – 3696, SD = 2401 ; r = . 99	BL = 0.8 PCA + 17.5, SD = 10.8 ; r = . 99	HC= 0.48 PCA + 14, SD = 6.63 ; r =. 98
Battisti *	=174 APC – 3665, SD = 434 ; r = .99	= 0.9 APC + 11.5, SD = 4; r= . 99	= 0.6 APC + 9.72, SD = 2.4 ; r= . 98
Dombrowski *	= 174 APC – 3732, SD = 1262; r=.99	= 1.06 APC + 6.64, SD = 7.8; r=. 99	= 0.721 APC + 5.3, SD = 5.3; r = . 98
Gairdner *	= 206 APC – 5051, SD = 2672; r = . 98	= 0.89 APC +13.6, SD = 13; r =. 99	= 0.5 APC + 13.94, SD = 6.5; r = . 98
Lubchenco *	= 163 APC – 3375, SD = 1303; r =. 99	= 1.25 APC + 2.5, SD = 7.1; r =. 99	= 0.58 APC + 10.5, DS = 4.8; r =. 97
Usher-McLean *	= 177 APC – 3741, SD = 1350; r =. 99	T= 1.11 APC +7, SD = 8.35; r =. 99	= 0.81 APC + 3.1, SD = 6.2; r=.99

* the original data can be found in the respective references.

Table 2: Mathematical correlations between PCA and parameters of growth in the differents charts.

Périods in weeks	d BW g	d BL cm	d HC cm	dBWg/dBLcm	dBWg/dHCcm	dBLcm/dHCcm
26-28	115 (70- 160)	1 (.85-1.15)	1.1 (0.9 -1 .2)	115 (35-115)	110 (100-133)	0.9 (0.95-1)
28-30	145 (100- 190)	1.13 (0.63-1.63)	0.9 (0.7 – 1.3)	125 (90-160)	164 (115-213)	1.34 (0.44-2.24)
30-32	170 (108-232)	1.2 (.94– 1.54)	0.7 (0.7-1.3)	182 (86-288)	242 (117-376)	1.35 (0.9-1.79)
32-34	208 (148-268)	1.23 (.94- 1.54)	0.8 (0.65-0.95)	178 (70-286)	253 (153-353)	1.56 (0.97-2.15)
34-36	242 (167-317)	1 (0.6 – 1.4)	0.7 (0.15-0.9)	272 (174-370)	392 (184-600)	1.5 (1.1-2.5)
36-38	213 (129 – 297)	0.8 (0.3 – 1.3)	0.5 (0.2-0.8)	273 (166-380)	459 (87-731)	1.8 (1.1-2.5)
38-40	143 (43-243)	0.7 (0.1 – 1.3)	0.33 (0.13-0.53)	310 (0- 645)	621 (0-1321)	2.4 (0.5-0.34)
40-42	70 (0 – 168)	0.25 (0 – 0.6)	0.17 (0 – 0.48)	280 (0 – 583)	420 (0 – 400)	1.47 (0- 1.25)
Mean	170 (57 – 283)	0.9 (.15 – 1.65)	0.6 (0.04-1.1)	223 (82-366)	355 (14-686)	1.66 (0.88 – 2.44)

Table 3: Analysis of velocities (weekly increments) for BW, BL and HC, and also the relative indices of them (data with their mean and 95 % confidence intervals values).

All these associations can be compared to each other with a very good reliability as the standard deviations are comprised between 6 and 8 % of variation. The following formulas resume the associative relationshipsand may be use in either senses: predicting the value of a parameter of growth according to a given post-conceptional age or vice versa.

Weight in g = 175 PCA weeks – 3665 (SD = 13 %)

Length in cm = PCA weeks + 11 (SD = 8 %)

HC in cm = 0.6 PCA weeks + 10 (SD = 6 %)

Analysis of the weekly increments by the 3 parameters of growth during the different periods of post-conceptional age

In this point, the different curves are examined one by one during the different «slices» of PCA. Each parameter of growth, in their absolute relative values are being considered in their increments for the corresponding periods.

Concerning the absolute values: the gains for weight are highest for the 34-36 weeks period; for length, this is for the 32-34 weeks period; and for head circumference, that is for the 28-30 weeks period. It is even only after that last period that length increment is trepassing the HC increment. The always more increasing influence of insulin and the so called "placental fatigue" on the other hand can explain these different profiles [2-4,8,12-14,73].

Concerning the relative values: one can observe that the highest values are found at the end of pregnancy. The disparity of body growth over head growth is obvious after 34 weeks, and over length that is obvious after 36 weeks. The significant correlations among the relative values of growth's parameters are found solely for the following ratios:

- [d W g / d HC cm] per week = 44 PCA – 1138, SD = 13 %, r = 0.973;
- [d L cm / d HC cm] per week = 0.094 PCA – 1.543, SD 14 %, r = 0.88;

On a clinical point of view, the strongest correlation is found when increment in weight is related to increment in HC, which is practical as these parameters are more easy to obtain than the length, even if

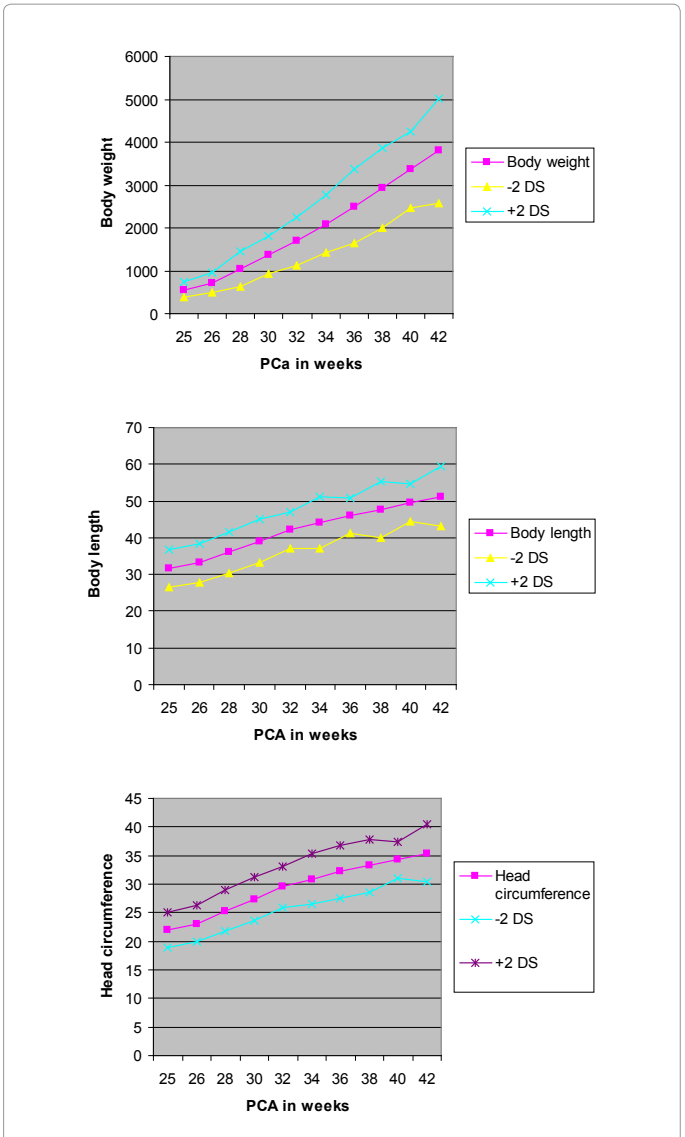

Figure 1: DOMBROWSKI chart: « PCA in weeks, BW in g, BL in cm, and Hc in.

that last parameter has very important value for appreciating «growth» [4,6,7].

Discussion

The normal growth during any time of life has always been important for the clinician. A ***«normal» growth*** is defined by the presence of parameters being comprised in normal values and presenting a sort of harmony between them. Normality is however differently defined among the existing charts: the mean values +/- 2 standard deviations, the centiles (from the 3 or 10th to the 97 or 90th centile, the mean values and the 90 or 95th confidence intervals. On the other hand, a growth is said to be ***abnormal*** if the parameters are insufficient or excessive in their absolute values, or if either their velocities are outside the normal values. The conditions leading to a normal growth allow to reduce:

- the complications due to hypoxia in utero, or birth asphyxia;
- and also the mortalities or morbidities following a prematurity, an abnormal growth.

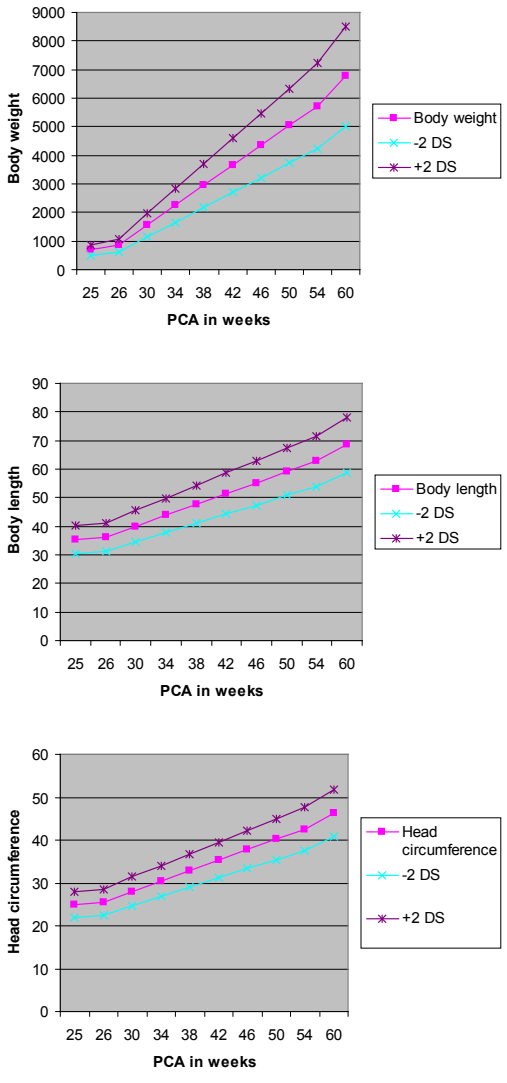

Figure 2: BATTISTI chart: « PCA in weeks, BW in g, BL in cm, and HC in cm.

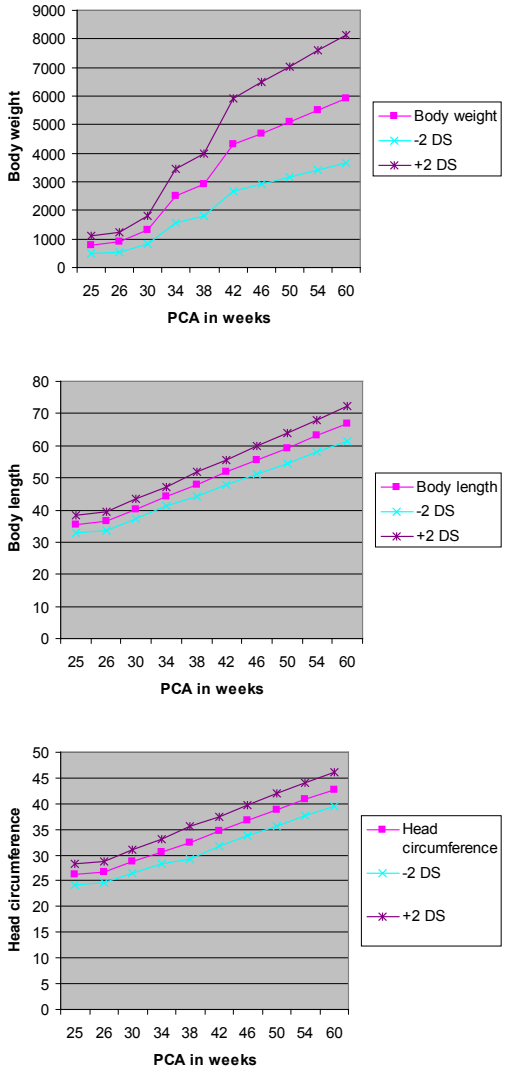

Figure 3: GAIRDNER chart: « PCA in weeks, BW in g, BL in cm, and HC in cm.

At the end, the most fragile babies being those born with a birth weight below 1000g or below 30 weeks. And also those combining a prematurity and growth retardation [2-5,8,9,14].

The body weight is the easiest parameter to obtain. It is supposed to resume growth in all its dimensions: the cerebral mass (14-15 % of BW), the lentgh (the bones represent 35- 40 % BW) and the soft tissues (the skeletal muscles: 20-25 % BW, the skin and its annexes: 15 % BW, the white adipose tissue: 2 % BW at 28 weeks and 14 % BW at term [4,8,11]. The body weight remains a major parameter, but other (mainly the HC) might have priority. And that is obvious in cases of intrauterine of postnatal growth retardation. For these reasons, it would be better to use charts satisfying the statistical parameters for normality of populations in the different parameters. What the BW is concerned, the «Lubchenco» and«Usher-Mclean» are questionable. The «Babson», «Dombrowski», «Gairdner» et «Battisti» respond to the statistical criteria of normality concerning the 3 parameters. Moreover, the last two charts remain valuable till 60 weeks PCA and hence should

perhaps more used in the neonatal units, and also during the 5 months after term. That can avoid the need to «correct» for prematurity the postnatal growth. The «Dunn» chart has values only for the BW. The first two charts («Babson» and «Dombrowski») should be used for a diagnostic purpose at birth. These type of charts do not offer the predictive correction due to noticeable changes observed during th first 2 weeks following birth (as it can be done by other type of charts: see «Dancis» for BW and «Gross» for HC).

The ponderal index and body mass index, even if criticized in the literature, have a real value after 34 weeks PCA for PI and after 36 weeks for BMI [4,8,73]. They should be used solely for diagnostic purpose at birth. The relative indices are clearly show different values during fetal life (Table 2).

In the specific situation of a fragile neonate, it is important for the clinician to have the possibility to appreciate the adequacy between the weekly observed growth and offered nutrition either by parenteral or enteral routes. The importance of nutrition in its quality, quantity an rapidity for an optimal long term development have extensively been studied [3,4,5,8,10,13,15,16,17,18-26,50,55,59-73].

In order to obtain that, it is important to plot the observed weekly increments for the parameters of growth on an appropriate chart. However, and as it is not always easy to get all the parameters, one may use two parameters of growth (BW and HC) which are combined in the following mathematical formula:

dBW in g / d HC cm = 44 PCA weeks – 1138 (SD = 13 %, r = 0.973, $p < 0.0001$

It allows two precise conclusions or predictions:

- If PCA is known, it can appreciate the adequacy of weekly growth. For examples: at 34 PCA weeks, 1 cm of gain in HC must be accompanied of a gain in BW of 358 g and vice versa; at 28 PCA weeks, these numbers are 94 g BW, and 422 g BW at term.
- If PCA is not known, it can predict the PCA from the observed ratio [d BW / d HC].

Conclusions

The neonatal growth's charts for a diagnostic purpose are not equivalent, mainly concerning the body weight. The combined growth's charts should instead be used to appreciate the postnatal growth of a prematurely neonate, and that till 20 weeks or 5 months after term.

Globally, the growth has to be appreciated by following several parameters, either by plotting them individually on a appropriate chart, either by using a relative index (a ratio between two parameters) which takes into account the variability over time of body weight and head circumference.

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