http:// ijp.mums.ac.ir
Original Article (Pages: 11625-11633)

Trends of Growth Rate among Iranian Infants: Comparison Exponential Model and Points Average Model and Related Factors

Seyede Shadi Nazari[1], Nima Motamed[2], Shahram Arsang-Jang[3], Yalda Ehsani Khanghah[2], *Ramazan Fallah[3]

[1]MSc, Student Research Committee. Department of Biostatistics and Epidemiology, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran.
[2]MD, Department of Health Care Management, Zanjan Social Health Research Center, Zanjan University of Medical Sciences, Zanjan, Iran.
[3]Department of Biostatistics and Epidemiology, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran.

Abstract

Background
Childhood growth factors play an essential role in the process of child development. Providing an accurate measurement for determining the growth rate predictors longitudinally has an advantage over a growth chart that only measures cumulative growth. This study aimed to determine the trends in growth rate and its effective factors among infants using two different methods.

Materials and Methods: This longitudinal study was conducted on 181 infants referred to healthcare centers of Zanjan, Iran, from April 2017 to April 2019. The growth rate using 9-time points was estimated for participants via Point Average Weighting (PAW) model and the exponential model. The generalized estimating equation (GEE) method was used to estimate predictors of infant's growth rate. The coincident and parallelism test was used to compare the growth rate between models.

Results: The mean growth rate of children in the PAW model and the exponential model in the first month were 298.2±109.2 and 299.4±115.6 gr/kg per month. The results showed that the two models' growth rate prediction ability is almost identical over time. The trend of growth rate was decreased significantly (AAPC=22.46% per month, P<0.0001) with a change-point in month ninth. The estimated growth rates based on two models coincided (P=0.885), and parallel (P=0.898) across 24 months. The associations between growth rate with variables mother job (B=9.4, P=0.005), breastfeeding (B=-9.3, P=0.005), and multi-fetal pregnancy (B=-18.9, P=0.005) were significant.

Conclusion
There was no difference between the two models when pediatricians apply them in office or other clinical settings. The multi-fetal pregnancy, job of mother, and exclusion breastfeeding were the most important predictor of growth rate, especially at the first nine months of age.

Key Words: Breastfeeding, Growth rate, Growth trend, Infants.

*Please cite this article as: Nazari SS, Motamed N, Arsang-Jang Sh, Ehsani Khanghah Y, Fallah R. Trends of Growth Rate among Iranian Infants: Comparison Exponential Model and Points Average Model and Related Factors. Int J Pediatr 2020; 8(7): 11625-633. DOI: **10.22038/ijp.2020.49454.3954**

****Corresponding Author:***

Dr. Ramazan Fallah, Department of Biostatistics and Epidemiology, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran.

Email: rfv@zums.ac.ir

Received date: Apr.23, 2020; Accepted date: Jun.22, 2020

1- INTRODUCTION

Childhood growth factors play an important and influential role in the process of child development that any uncontrolled malignancy and growth deficiency in this period will cause an adverse complication at an early age (1). The growth refers to changes in the size of the whole or different parts of the body. These changes are organized and somewhat happens predictably. Besides being an essential part of society, they are also part of a sensitive and vulnerable group to malnutrition. This group needs ideal living conditions because of their rapid growth and maximum desirable growth, and any inappropriate factors can hurt their growth (2). According to studies, the prevalence of growth disorders in developing countries is higher than in other parts of the world, and in most of these countries, the physical growth of children is weak and even below the standards (2).

Studies of growth disorder in Iran and different countries were different, and factors such as parental educations, their employment status, economic status of the family, duration of breastfeeding, the number of children, repeated care, and maternal awareness of how to properly care for a child can be useful in preventing child growth disorder (3). Monitoring and follow up of children is one of the essential proceedings in the health of children in the last two decades (4). Child growth monitoring is a reliable, simple, and inexpensive tool to record and checking their health status (5). Currently, the best criterion for assessing a child's health is its weight and height measurement, particularly in the first two years of birth. Therefore, the status of the child can be compared with that of the standard population of the same age by using growth curves (2). The growth rate as an epidemiological tool in assessing height and weight growth status of children has advantages over growth charts that only measure cumulative growth (6, 7). Choosing a suitable and accurate growth rate calculator can influence the assessment of growth status or even the relationship between effective factors. Many studies have been done with different methods to measure the growth rate of children in Iran and worldwide (3, 6-8). PAW and exponential relationships differ in the way the growth rate change when the birth weight and age increase by a constant amount, for constant increments in birth weight and age, a PAW growth would increase by a constant difference, and an exponential growth would increase by a constant ratio. PAW model is easy to perform and calculate. However, the Exponential model is essential to the understanding rate of change problems. This study aimed to determine the trend of growth rate and the predictors of an infant’s growth rate using exponential and point average weighting models, in addition to estimating the trend of growth rate across 24 months.

2- MATERIALS AND METHODS

This longitudinal/panel study, considering the recommended ratio of sample to the number of variables at least 10:1 for panel data (9), was conducted on 181 infants from the records of 24-month-old children referred to primary health care centers in Zanjan, Iran. About six representative healthcare centers, including three urban health centers and three rural health centers as a cluster, were selected randomly, then 29 samples were selected randomly from each center. Infant’s health care experts provided the measurements with high accuracy from April 2017 to April 2019.

2-1. Inclusion and Exclusion criteria

The Iranian infants younger than 24 months at the time of data collection were considered as inclusion criteria. Infants with a history of genetic or congenital disorders, chronic infection disease, disability, growth disorder, and incomplete information were excluded from the study.

2-2. Measurements

Data were extracted through a health registration system that contains maternal demographic information including height, weight, education, maternal residence and job, sex of infant, duration of breastfeeding, duration of exclusive breastfeeding up to 6 months, gestational age, birth weight, and child weight at first, second, fourth, sixth, ninth, twelfth, eighteenth and twenty-fourth months. In this research, an infant’s growth rate as the response variable was computed from PAW model and the exponential model; Points average weight model:

$$G.V = \frac{2000(W_{i+1}-W_i)}{(M_{i+1}-M_i)(W_{i+1}+W_i)}$$

Exponential model:

$$G.V = \frac{1000\ li(\frac{W_{i+1}}{W_i})}{(M_{i+1}-M_i)}$$

Where $W_{(i+1)}$ and W_i are infant's birth weight in the month (i+1) and (i), respectively. $M_{(i+1)}$ and M_i are infant's age in month (i+1) and (i), respectively and i=0,1,2,4,6,9,12,18,24. G.V unit is g/kg/month, which shows the gained weight in grams per one kg of the infant's weight, in the i^{th} month.

2-3. Data Analyses

These analyses were performed in SPSS software version 22.0, with statistical significance by 95% confidence interval (95% CI). The growth rate was assumed autocorrelated within individuals due to its repeated measurements. Therefore, the marginal modeling approach and GEE methodology (for estimating the model parameters) were used to examine the relationship between the growth rate and explanatory variables with accounting the autocorrelation property (9).

3- RESULTS

This retrospective cohort study was conducted on 181 infants under two years in Zanjan city, Iran. The characteristics of participants are shown in **Table.1**. As a result, about 93 (51.4%), and 94 (51.9%) of participants were girls and from urban regions, respectively. The mean± standard deviation (SD) of maternal age, birth rank, and maternal pregnancy age were 28.4(4.7) years, 1.9 (0.8) child, and 38.7 (1.1) weeks, respectively. Also, 13 (7.5%) of the children were twins.

Table-1: Baseline characteristics of the participants (n = 181).

Characteristics	Sub-group	Number (%)
Residence	Urban	87 (48.1)
	Rural	94 (51.9)
Child gender	Girl	88 (48.6)
	Boy	93 (51.4)
Mother's job	Employed	48 (26.5)
	Housewife	133 (73.5)
Mother's education	Under Diploma	106 (58.6)
	Diploma	29 (16)
	College	46 (25.4)
Weight gain during pregnancy status	Normal	167 (92.3)
	Abnormal	14 (7.7)
Multi-fetal pregnancy	One	168 (92.7)

	Two	13 (7.5)
Under special care during pregnancy	Yes	101 (55.8)
	No	80 (44.2)
Exclusive breastfeeding up to 6 months	Yes	115 (63.5)
	No	66 (36.5)
Duration of Breastfeeding	<6 Months	66 (36.5)
	6-12 Months	13(7.2)
	12-18 Months	15(8.2)
	18-24 Months	87 (48.1)

The mean growth rate of children in the PAW model and the exponential model in the first month were 298.2 ± 109.2 and 299.4 ± 115.6 gr/kg per month. The results show that the two models' growth rate prediction ability is almost identical over time (**Table.2, and Figure.1**). The Generalized Estimation Equation (GEE) model was used to investigate the growth rate factors longitudinally in both PAW and the exponential models. The association of the infant's growth rate with the mother's occupation, multi-fetal pregnancy, and exclusive breastfeeding factors was statistically significant (P<0.001, **Figure.2**).

Table-2: The trend of children growth rate using exponential and average weight models.

Time (month)	Growth velocity			
	PAW model		Exponential model	
	Mean	SD	Mean	SD
1st	298.2	109.2	299.4	115.6
2ed	211.1	92.6	213.9	93.5
4th	107.8	41.2	108.4	41.8
6th	73.3	36.5	73.6	36.9
9th	41.8	25.2	41.2	21.8
12th	32.2	17.2	31.7	17.0
18th	19.3	7.7	19.1	7.8
24th	15.4	6.7	15.5	6.6

SD: Standard deviation.

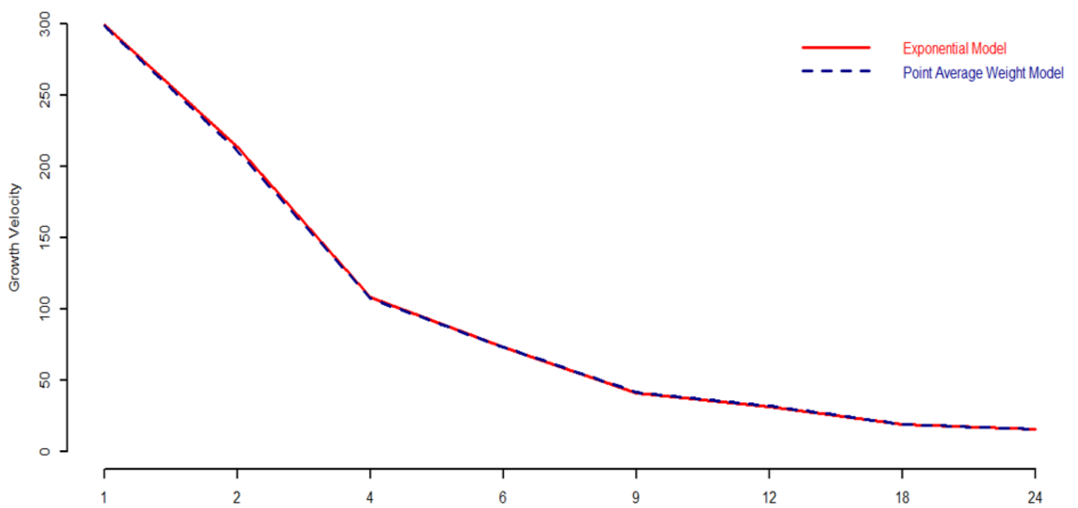

Fig.1: Comparison the Exponential model with PAW model of infant's growth rate.

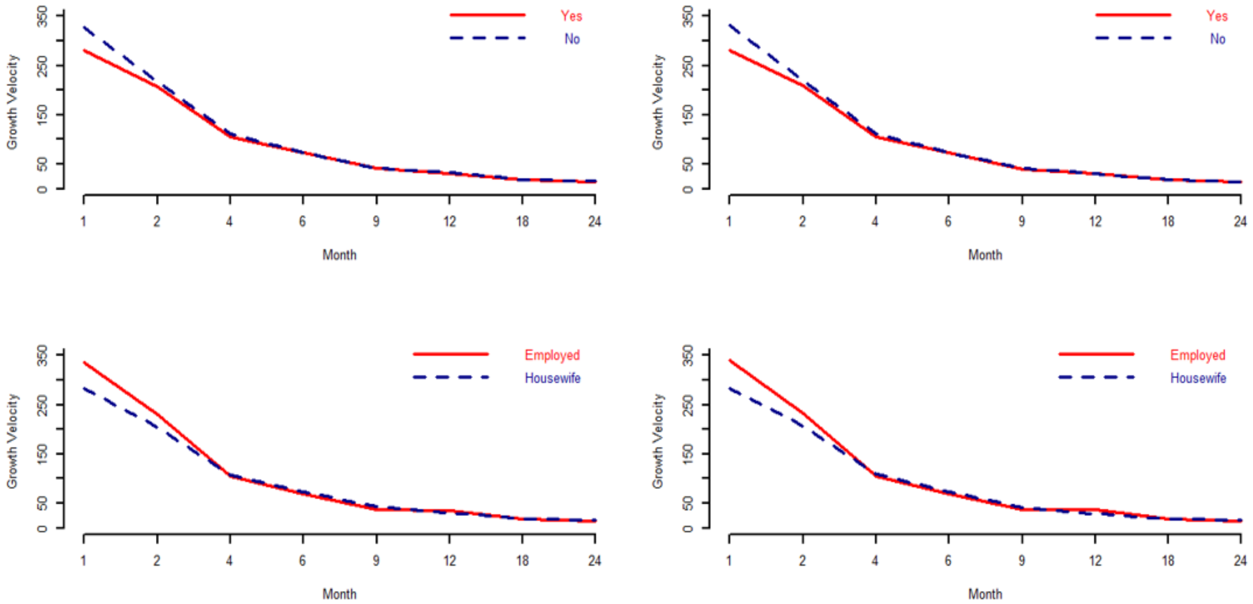

Fig.2: Comparison of PAW model with Exclusive breast feeding (left above), by Mother's job (left below), by Exclusive breast feeding (right above), by Mother's job (right below). PAW: Point Average Weighting.

According to the results of **Table.3**, the infant growth rate of employed mothers was 9.4 gr/kg higher than that of the housewife group. According to the exponential model, over time, the infant's growth rate of employed mothers was 9.9 gr/kg higher than that of the housewife group (**Table.4**). The association between growth rate and the rest of the variables was insignificant (P>0.05). The significant downward trend with one change point in the 9th month of birth was estimated for the infant growth rate trend. The average percent change of growth rate was -22.46% (P<0.001) per month for the first segment and -5.7% (P<0.001) per month for the second segment. The average percent change was estimated at -11.9% (95% CI: -10.5, -16.7) during the 24 months.

Table-3: The predictors' growth rate (average weight model) using marginal model (GEE).

Factor	Coefficient estimates	Standard deviation	95% CI		Wald statistic	P-value
			Lower	Upper		
Mother Job(employed/ housewife)	9.4	2.1	5.3	13.4	20.6	0.005
Multi-fetal pregnancy (yes/no)	-18.9	2.6	-24.0	-13.8	52.6	0.005
Exclusive breastfeeding (yes/no)	-9.3	2.1	-13.5	-5.2	19.3	0.005

CI: Confidence interval, GEE: Generalized Estimating Equation.

Table-4: The predictors of growth rate (Exponential model) using marginal model (GEE).

Factor	Coefficient estimates	Standard deviation	95% CI		Wald statistic	P-value
			Lower	Upper		
Mother Job(employed/ housewife)	9.9	2.1	5.8	14.1	21.9	0.005
Multi-fetal pregnancy (yes/no)	-19.6	2.7	-24.9	-14.4	53.6	0.005
Exclusive breastfeeding (yes/no)	-9.6	2.1	-13.8	-5.4	20.0	0.005

CI: Confidence interval, GEE: Generalized Estimating Equation.

4- DISCUSSION

In this study, we compared the results of two mathematical models to estimate the Growth rate in children aged ≤2 years. Our results showed that the estimated growth rate was almost identical by both two mathematical models, whereas the prediction ability of the two models was similar. Furthermore, our longitudinal study showed that variables housewife mothers, multi-fetal pregnancy, and exclusive breastfeeding were negatively associated with the growth rate of infants. The PAW and exponential models provide the same findings. Although both models utilized simple algebraic equations, the average weight model was developed using a more straightforward equation by which the GV can be manually calculated in the office without applying a calculator. Although both equations obtain a similar result in practical fields, theoretically are quite different. With a mathematical approach and using simple examples, we can show the two models do not obtain identical results under any circumstances. However, in a status adapted to human biology, two models should obtain identical results (**Appendix.1**).

Despite approximately identical results, both two models in our subjects, Patel et al. reported a higher performance of the exponential model than that of two points average model (10). In addition to similar descriptive results of two models, the two models' analytical findings were almost identical. It shows that not only two models obtained similar results on average, but also they provided similar findings on an individual level. Thus we suggest two models can be utilized to estimate the status of growth rate at the community level for public health aims and strategies and individual level to manage the children in the office for therapeutic aims and strategies in the office or other clinical settings. In a large cohort study, Schwinger et al. suggested that growth rate measures are valuable to identify the children at a higher risk of death (11). Neonatal mortality rate (NMR) and infant mortality rate (IMR) are the most important indexes to evaluate the health status of associated communities. Thus this predictive ability can help the clinicians in clinical settings and health policymakers to implement public health strategies to promote the health of the related communities (12). On the other hand, Maruyama et al. reported that the values of growth rate during hospitalization in the NICU might have a relationship with even neuro-developmental outcomes (13). On the other hand, a higher growth rate can raise the risk of some adverse health outcomes in the next decades of life (14, 15).

These results show that not only is growth rate a valuable index to predict the neonates at risk of death, but it is valuable for the prediction of other significant health problems. However, the calculation of the growth rate is more complicated than that of usual weight measurements in healthcare settings and offices. Furthermore, in this approach, it is required at least two measurements in a period of time. In a critical situation, this is not possible. However, if the previous reliable data of patients are available, the calculation of growth rate is possible even in critical conditions of patients.

On the other hand, there are no available standards for the growth rate to compare in contrast to weight gain curves and standards suggested by the World Health Organization (WHO) (16). Moreover, the related periods to calculate the growth rate is not currently defined. As mentioned above, we evaluated the association between some variables, including mother employing, exclusive breastfeeding, multi-fetal pregnancy, residency, sex, birth order, and the number of siblings with growth rate using marginal models (GEE). The outcome variable (growth velocity) was estimated by two models of two point's average model and the exponential model. Based on both models, a significant association was found between multifetal pregnancy, the job of mother, and exclusion breastfeeding with the velocity of growth. An association between growth rate and multi-fetal pregnancy can be expected. The twin neonates usually have a lower weight than singleton at birth. It was suggested that the utilization of twin-specific nomogram might categorize twins into young gestational age with a less probability and thus obtain more valid predictions to identify the neonates at risk for death (17). Thus, to compensate for lower birth weight in twins at birth, a higher growth rate may occur in twins than that of singletons, our results also confirm this result. Our results also showed that the neonates of employed mothers had a higher growth rate than those of unemployed mothers. The employed mothers likely feed their newborns with a more frequency using formula. Previous studies showed that bottle-fed infants using formula have a higher weight gain than breastfed (18). Based on our findings, infants who had exclusive breastfeeding had a lower growth rate than neonates who had not. These neonates usually fed with formula. In a systematic review, Appleton et al. showed that Infant formula feeding practices maybe lead to rapid weight gain in related neonates (19). We showed the two famous equations, two-point average models and exponential models, obtained almost identical results, to calculate the growth rate in children two years and less. We also mathematically confirmed two models in a status adapted with human biology should obtain the identical results (refer to **Appendix.1**), although two equations do not obtain the similar results in all conditions (refer to **Appendix.1**). We also showed that exclusive breastfeeding and employing had a negative association with growth rate based on two equations. Our study also showed that twins had a higher growth rate than that of a singleton. However, our study had some limitations. Although the identical results of two equations, particularly to determine the associations, may indicate the validity of these two tools, to directly evaluate this validity, the prospective studies with discerned outcomes should be conducted.

Appendix 1

With a mathematical approach and considering $W_{n+1}/W_n = R$, the different parts of two equations can be converted to $D = \frac{R-1}{R+1}$, and $\ln R$ for average weight and exponential models, respectively. We consider the identical part of two models to be equal to $S = \frac{1000}{M_{n+1} - M_n}$. Thus, the growth velocity formula simply converts to G.V=R*S. Assuming $R = 1$, meaning that no increase occurs in weight for a period of time, both equations obtain a logical and expected finding, D= 0 and thus G.V=0. When the increase in weight is too high or we consider a long period of time, that can lead to very increase in weight of children the results of two equations become quite different. For instance, assuming R=5, while the different part of points average model obtains D= 4/3 and thus, G.V=4/3D$\cong$1.33D, the different part of the exponential model becomes D= $\ln 5 = 1.8$ and thus G.V=1.61D. Assuming $R \to \infty$, while the different part of points average model becomes equal to 1 the different part of the exponential model become ∞. Finally, one may claim that the values of different part of the point average model theoretically vary between 0 to 1, while these values vary between 0 to ∞ for exponential model. However, as mentioned above for practical aims, an increase in weight generally is very lower than the weight itself in a short period of time, and thus two models obtain almost identical results.

4-1. Study Limitations

This study, however, had some limitations. It is a longitudinal study that cannot investigate the causality. The effective factors on growth rate have not been measured longitudinally. This study did not consider the relationship between the type of health services utilization and economic factors on the growth rate.

5- CONCLUSION

Based on the results, the two-point average and exponential models obtained similar results in descriptive and analytical analyzes. There is no difference between the two models when pediatricians apply them in office or other clinical settings. Among various potential predictors, a significant association was found between multi-fetal pregnancy, the mother's job, and exclusion breastfeeding with the velocity of growth based on both models.

6- ACKNOWLEDGMENTS

The authors would like to thank all honorable officials and personnel of Zanjan University of Medical Sciences who sincerely helped during this study. The current study was approved from Zanjan University of Medical Sciences by grant no. IR.ZUMS.REC.1397.034.

7- CONFLICT OF INTEREST: None.

8- REFERENCES

1. Kosaryan M, Vahidshahi K, Shafaat B, Abaskhanian A, Azizi S, Shahrokh SH, et al. Screening of Developmental Problem, Day care Centers, Sari, 2006. J-Mazand-Univ-Med-Sci. 2007;17(59):69-75.

2. Montazerifar F, Karajibani M, Mohammadi M. Comparison Of Growth Pattern In Children Under 6 Years With Standard National Center For Health Statistics (Nchs). Zahedan Journal Of Research In Medical Sciences (Tabib-E-Shargh). 2005;7(1):39-47.

3. Fallah R, Kazemnejad A, Shoghli A, Vahabi N. Growth velocity of children and its affective factors in northwestern Iran: A longitudinal study using marginal models. MJIRI. 2018;32(1):414-9.

4. Ehsanpour S, Abdyazdan Z, Javanmardi Z. Comparison of growth indexes in children under 2 years with low birth weight and normal. Shahrekord University of Medical Sciences Journal. 2001;3(1):69-74.

5. Arifeen SE, Black RE, Caulfield LE, Antelman G, Baqui AH, Nahar Q, et al. Infant growth patterns in the slums of Dhaka in relation to birth weight, intrauterine growth retardation, and prematurity. The American Journal of Clinical Nutrition. 2000;72(4):1010-7.

6. Ayatollahi SMT, Haem E, Sharafi Z. Growth Velocity of Infants From Birth to 5 Years Born in Maku, Iran. Glob J Health Sci. 2015;8(2):56-63.

7. Hosseini S-M, Maracy M-R, Sarrafzade S, Kelishadi R. Child Weight Growth Trajectory and its Determinants in a Sample of Iranian Children from Birth until 2 Years of Age. Int J Prev Med. 2014;5(3):348-55.

8. Patel AL, Engstrom JL, Meier PP, Kimura RE. Accuracy of Methods for Calculating Postnatal Growth Velocity for Extremely Low Birth Weight Infants. Pediatrics. 2005;116(6):1466.

9. Zhao C, Sun PP. Doing Research in Applied Linguistics: Realities, Dilemmas, and Solutions: Jim McKinley and Heath Rose (eds) London & New York: Routledge, 2017, xi+ 262 pp. Taylor & Francis; 2019.

10. Patel AL, Engstrom JL, Meier PP, Jegier BJ, Kimura RE. Calculating postnatal growth velocity in very low birth weight (VLBW) premature infants. J Perinatol. 2009;29(9):618-22.

11. Schwinger C, Fadnes LT, Van den Broeck J. Using growth velocity to predict child mortality. The American Journal of Clinical Nutrition. 2016;103(3):801-7.

12. Chung S-H, Choi Y-S, Bae C-W. Changes in the neonatal and infant mortality

rate and the causes of death in Korea. Korean J Pediatr. 2011;54(11):443-55.

13. Maruyama H, Yonemoto N, Kono Y, Kusuda S, Fujimura M, Neonatal Research Network of J. Weight Growth Velocity and Neurodevelopmental Outcomes in Extremely Low Birth Weight Infants. PLOS ONE. 2015;10(9):e0139014.

14. Horbar JD, Ehrenkranz RA, Badger GJ, Edwards EM, Morrow KA, Soll RF, et al. Weight Growth Velocity and Postnatal Growth Failure in Infants 501 to 1500 Grams: 2000–2013. Pediatrics. 2015;136(1):e84.

15. Wiedmeier JE, Joss-Moore LA, Lane RH, Neu J. Early postnatal nutrition and programming of the preterm neonate. Nutrition Reviews. 2011;69(2):76-82.

16. The WHO Child Growth Standards. https://www.who.int/childgrowth/standards/en/.

17. Mendez-Figueroa H, Truong VTT, Pedroza C, Chauhan SP. Growth among Twins: Use of Singleton versus Twin-Specific Growth Nomograms. Am J Perinatol. 2018;35(02):184-91.

18. Azad MB, Vehling L, Chan D, Klopp A, Nickel NC, McGavock JM, et al. Infant Feeding and Weight Gain: Separating Breast Milk From Breastfeeding and Formula From Food. Pediatrics. 2018;142(4):e20181092.

19. Appleton J, Russell CG, Laws R, Fowler C, Campbell K, Denney-Wilson E. Infant formula feeding practices associated with rapid weight gain: A systematic review. Maternal and Child Nutrition. 2018;14(3):e12602.