



Growth velocity of children and its affective factors in northwestern Iran: A longitudinal study using marginal models

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Abstract

Background: Child growth is an important health indicator in human's lifespan. Evaluating growth variations in infants and children is highly important. This study was conducted to evaluate the risk factors of child growth retardation and determine childhood growth velocity in Zanjan province, Iran.

Methods: This longitudinal study was conducted on 7892 children aged 0 to 2 years in Zanjan province in 2013. The sampling method was multi-stage cluster sampling. To determine the growth velocity, 2- pointed model was used. We applied the marginal models of generalized equation estimators (GEE). The related curves were obtained using LOWESS method, and data were analyzed using R Version 2.14.1.

Results: In this study, 3879 (49%) of the participants were female, and the mean age of mothers was 27.1±5.4 years. Growth velocity had a significant association with gender, mother's residency, multiple pregnancies, gestational age, and exclusive breastfeeding ($p<0.001$). A significant association was observed between gender and weight growth velocity ($p<0.001$). Moreover, exclusive breastfeeding had a significant association with weight growth velocity ($p<0.001$).

Conclusion: Growth velocity in girls was slightly higher than in boys, however, no considerable difference was found between height growth velocity of girls and boys. The findings of this study also indicated that each month increase in exclusive breastfeeding leads to less growth velocity in children. So, exclusive breastfeeding is strongly recommended to prevent childhood obesity.

Keywords: Growth, Marginal model, Growth velocity, Weight

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Introduction

Child growth is an important health indicator in human's lifespan (1). Evaluating growth variations is highly important, as it not only can indicate health promotion and public health conditions in a related society, but it can also denote intergeneration variations of growth and development (2, 3). Weight and height indices have a critical role in the evaluation of child health and, consequently, their continuous and periodic assessment is essential for monitoring child growth (4). An inappropriate increase in weight and height is usually considered an indicator for growth retardation. Several factors play a role in children's growth status, including parent's education level, parent's employment situation, household economy, family size, and maternal health literacy (5). Regular and systematic evaluation of children's weight may lead to early

identification of growth retardation and prevention of related complications (6). According to a report of WHO, over 30% of under 5 year-old children have growth retardation, of whom 20% and 80% have a low weight and height, respectively (7). On the other hand, Iran is one of the 7 countries in which the prevalence of childhood obesity is high (8). However, a national survey showed that 9.5% of under 5 year-old children had a moderate or severe low weight, and the prevalence of a lower height and weight was 13.9% and 5.3%, respectively (9). Longitudinal models are appropriate tools to evaluate the trend of growth over time. Nowadays, these models are widely applied in medical, behavioral, and psychiatric sciences. One of the dominant characteristics of longitudinal approaches is the repeated measurement of observations.

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↑What is "already known" in this topic:

According to the literature, exclusive breastfeeding during the first 6 months of life prevents childhood obesity.

→What this article adds:

This study strongly recommends exclusive breastfeeding to prevent childhood obesity.

Consequently, separating the time-related effects from group effects may be possible by applying these models. Concerning the correlation between observations, it is important to apply those models in which hierarchical structures of data and their correlations are considered. The marginal model is one of the longitudinal models that can obtain a more precise evaluation of growth retardation related factors that consider correlations between the data (10). This study was conducted to evaluate the growth-related risk factors and determine childhood weight trends in Zanjan province, Iran.

Methods

Study population and sampling

This longitudinal study was conducted in Zanjan province, with a total population of 1020000 (49% female population). Zanjan province is located at the northwest of Iran, with 8 different districts and semi-mountainous climate. The target population was all the neonates in Zanjan province who were born from March 2010 to March 2012. In this longitudinal study, we used the health records of children younger than 2 years who referred to health care settings. The data of weight and height of the children were available at birth and at 1, 2, 4, 6, 9, 12, 18, and 24 months. The study sample was selected using a multi-stage cluster sampling technique. In the first stage, 4 cities were randomly selected among 8 cities of this province. In the second stage, 32 centers were randomly selected from 82 governmental urban and rural health centers. The rural health centers typically cover more than 98% of pregnant women, while urban health centers cover about 75%. At the next step, all the health files of neonates younger than 2 years in these 32 centers were evaluated, and a total of 8286 records were included in the study. Sample size was estimated 1240 children based on formula of Cochran (11):

$$n = \frac{(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 \cdot \sigma^2}{d^2} = 1240$$

$$\sigma = 250, \beta = 0.2, \alpha = 0.05, d = 20$$

As we had $m = 9$ repetition of children's birth weight, the required sample size was calculated assuming the correlation coefficient of $(r) = 0.7$, that is: $(1 + (m-1) \cdot r) \cdot n = 8200$ (11).

Data collection and variables under study

In this research, children's growth velocity was considered as the main outcome (dependent variable). For each child, height and weight were extracted based on existing data in the health files. Data of the health files were collected by expert health workers. Children's weight was measured using regular calibrated and standardized baby scales (Seca, Germany), with an accuracy of 100 grams. Height was measured using a meter with an accuracy of 1 centimeter.

In addition, we considered residency (urban or rural), child's gender (male or female), mother's educational level (illiterate, primary, secondary school, diploma, college degree), maternal weight (kg) and height (cm) in the

early phase of pregnancy, job status of the mother (homemaker, employee), maternal age (year), multiple pregnancy (1, 2, and more), breast feeding duration, duration of exclusive breast feeding, children's rank in the family (1, 2, 3, 4 and more), and gestational age (week) as the potential indicators (independent variables) for the growth velocity in modeling process. Data were collected by a predesigned checklist, which was filled out based on registered data in the health records of children.

Inclusion and exclusion criteria

All babies younger than 24 months at the time of data collection were eligible to enter the study. Babies with the history of any known genetic or congenital disorders, any mental or physical disability, and incomplete record due to interruption in the continuum of the care were excluded from the study.

Statistical analysis

In this research, because the growth velocity values were repeatedly measured for each infant, a correlated response variable was available for each participant. In this context, the marginal modeling approach and generalized equations estimation (GEE) methodology (for estimating the model parameters) were used to assess the relationship between the outcome (growth velocity) and a variety of explanatory variables, while accounting for the correlation between response data. The applied marginal model can be written as follows:

$$g(\mu_{ij}) = X'_{ij}\beta,$$

$$i = 1, 2, \dots, n, j = 1, 2, \dots, n_i$$

Where β denotes the regression coefficient vector, X_{ij} denotes the matrix of explanatory variables, and μ_{ij} is the expected value of the response data for i th infant in the j th time of measurement (10).

To determine the growth velocity for each infant at each time of measurement, 2-pointed models of weight and height were used. Growth velocity was calculated using the following formula:

$$G.V = \frac{2000 \cdot (W_{n+1} - W_n)}{(M_{n+1} - M_n)(W_{n+1} + W_n)}, n = 0, 1, \dots, 24$$

Where W_n and M_n indicate the weight and age of the child, n th month and W_{n+1} and M_{n+1} indicating the weight and age of child in $n+1$ th month, respectively. In addition, the height velocity was calculated as follows:

$$G.V = \frac{200 \cdot (H_{n+1} - H_n)}{(M_{n+1} - M_n)(H_{n+1} + H_n)}, n = 0, 1, \dots, 24$$

Where H_n and H_{n+1} indicate the height of child in months of n and $n+1$, respectively. In addition, W_{n+1} and M_{n+1} indicate the weight and age of the child in $n+1$ th month (12). The nonparametric curves estimation was

plotted using the LOWESS method (13). Statistical analysis was performed using the STATA software, Version 12.0 (STATA Corp., Texas, and USA). We were committed to protect participants' privacy and confidentiality of their personal information.

Results

This was a longitudinal study conducted on 7892 children aged 0 to 2 years in Zanjan province, Iran. A total of 394 files were discarded from 8286 files, and 7892 were included in the study. Of the participants, 4013 (51%) were boys. The mean age of mothers was 27.1 ± 5.4 years, and 4429 (56%) of mothers did not have a high school diploma, 1837 (23%) had high school diploma, and 1637 (21%) had a university degree. Employment rate was 14.3% among mothers, and 50.2% of the mothers resided

in rural areas. More details are reported in Table 1.

The mean velocity of weight growth and related standard errors are displayed in Table 2 & Fig 1. According to our data, 3.5% of weight growth velocity pause belonged to children aged 4 to 6 months and 12 to 18 months (3.3%). The results revealed that children had a higher rate of growth velocity in the first month. There was a significant difference between male and female children in the increasing rate of growth in the second month, 4 to 6 months, and 9 to 12 months of life. The highest percent of height growth velocity belonged to children aged 12 to 18 months and the lowest to those 9 to 18 months. Height increase was statistically and significantly different between the 2 genders in the second month and at 16 to 18 months. More details are reported in Table 3 & Fig 1.

The results of the marginal model revealed a significant

Table 1. Distribution of demographic characteristics of mothers and children under two years of age

Characteristics	Category	Frequency	Percent
Child's gender	Boy	4013	50.8
	Girl	3879	49.2
Mother's education	High-school	4429	56.1
	Diploma	1837	23.3
	Higher education	1626	20.6
Place of residence	Urban	3961	50.2
	Rural	3931	49.8
Mother's job	Homemaker	6767	85.7
	Employee	1125	14.3
Mother's age	Under 18 years	434	5.5
	18-35	6936	87.9
	≤ 35	522	6.6
Children rank in family	1	3107	39.4
	2	3270	41.4
	3	1107	14.0
	≤ 4	408	5.2
Gestational age	Under 37 weeks	1107	14.0
	≤ 37 weeks	6785	86.0
Exclusive Brest feeding	6 months	4190	53.1
	Under 6 months	3702	46.9
Multiple pregnancy	1	7707	97.7
	≤ 2	185	2.3

Table 2. Frequency distribution of weight growth of children

Age (month)	weight growth velocity (grs/kg)			weight growth velocity (grs/kg)		p (t-test)
	Growth failure	Stunted growth	Natural growth	Girls	Boys	
	N	%	N	%	Mean \pm SD	Mean \pm SD
0-1	129	1.4	110	1.6	298.8 \pm 111.5	301.1 \pm 117.1
1-2	97	1.2	90	1.1	215.4 \pm 90.0	229.8 \pm 95.8
2-4	94	1.2	120	1.5	112.1 \pm 38.5	113.2 \pm 39.8
4-6	121	1.5	156	2.0	75.2 \pm 30.4	74.3 \pm 31.0
6-9	49	0.6	32	0.4	43.7 \pm 18.9	42.7 \pm 19.5
9-12	134	1.7	126	1.6	32.5 \pm 17.2	31.2 \pm 17.2
12-18	37	0.5	24	0.3	21.0 \pm 8.7	20.0 \pm 8.6
18-24	62	0.8	73	0.9	16.5 \pm 7.7	16.2 \pm 7.4

Table 3. Frequency distribution of height growth of children

Age (month)	Height growth velocity (cm/m)				height growth velocity (cm/m)		(t-test)
	Stunted growth		Natural growth		Girls	Boys	
	N	%	N	%	Mean \pm SD	Mean \pm SD	
0-1	118	1.5	7774	98.5	8.4 \pm 3.8	8.6 \pm 4.2	
1-2	124	1.6	7768	98.4	7.1 \pm 3.5	7.4 \pm 3.8	
2-4	129	1.6	7763	98.4	4.3 \pm 1.6	4.4 \pm 1.7	
4-6	138	1.7	7753	98.3	3.3 \pm 1.5	3.4 \pm 1.6	
6-9	108	1.4	7784	98.6	2.3 \pm 0.9	2.2 \pm 0.9	
9-12	70	0.9	7822	99.1	1.9 \pm 0.8	1.8 \pm 0.9	
12-18	68	0.9	7824	99.1	1.2 \pm 0.4	1.3 \pm 0.4	
18-24	89	1.1	7803	98.9	1.0 \pm 0.4	0.9 \pm 0.3	

Table 4. Marginal model (GEE)* results for assessing the relationship between different indicators and weight growth velocity

Characteristics	Category	B**	SE***	95%CI****		P (GEE)
				LL	UL	
Child's gender	Girl	1.80	0.36	1.14	2.45	<0.001
	Boy					
Multiple pregnancy	1	12.5	1.10	10.34	14.74	<0.001
	2≤					
Place of residence	Urban	0.71	0.36	0.02	1.45	0.045
	Rural					
Mother's job	Homemaker	-2.73	0.51	-3.74	1.73	<0.0001
	Employee					
Duration of exclusive breastfeeding		-1.10	0.24	-1.57	-0.63	<0.001

* Generalized Estimating Equation

** Estimate of the model parameter

*** Standard error of the estimate

**** CI=Confidence Interval; LL=lower limit, UL=upper limit

Table 5. Marginal model (GEE)* results for assessing the relationship between different indicators and height growth velocity

Characteristics	Category	B**	SE***	95%CI****		P (GEE)
				LL	UL	
Child's gender	Boy	0.56	0.14	0.28	0.83	<0.001
	Girl					
Multiple pregnancy	1	3.53	0.48	2.60	4.46	<0.001
	2≤					
Place of residence	Urban	0.84	0.14	0.57	1.12	<0.0001
	Rural					
Duration of exclusive breastfeeding		0.25	0.10	0.05	0.44	0.015

* Generalized Estimating Equation

** Estimate of the model parameter

*** Standard error of the estimate

**** CI=Confidence Interval; LL=lower limit, UL=upper limit

association between gender and weight growth velocity ($p < 0.001$), so that after removing the effect of other variables, weight growth velocity in female children was 1.8 g/kg more than male children. Our results also showed that the weight growth velocity of children whose mothers resided in urban areas was higher (0.71g) than those in rural areas. Also, exclusive breastfeeding had a significant association with weight growth velocity, where a 1 month decrease in exclusive breastfeeding led to 1.1 g/kg decrease in weight growth velocity (Table 4). Similar to weight growth velocity, we also obtained a significant association among growth velocity and child's gender, residency of the mother, and exclusive breastfeeding (Table 5).

Discussion

We evaluated the trends in weight and height growth and related factors in children younger than 2 years. In fact, we evaluated growth velocity instead of directly evaluating weight or height. Determining factors that affect growth, particularly in early years of life, can help the policymakers to develop preventive health programs at the community level. Thus, periodical studies should be conducted in this context to determine the effectiveness of these programs. Therefore, we evaluated the growth ve-

locity applying the 2-pointed model, as previously mentioned. This model usually obtains more accurate esti-

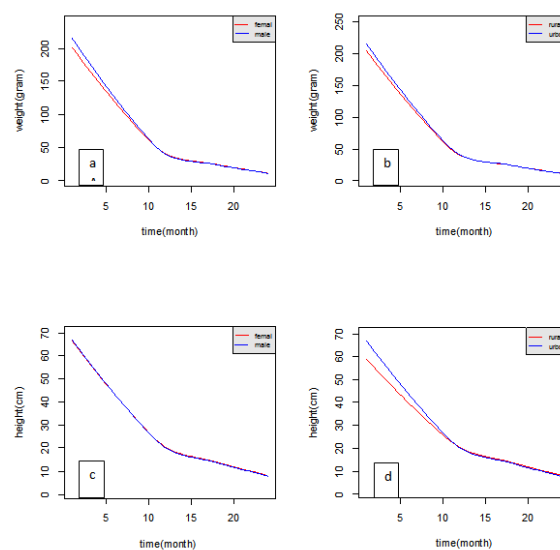


Fig. 1. Weight growth velocity curves: (a) Weight growth velocity curve by gender. (b)Weight growth velocity curve by place of residence(c) Height growth velocity curve by gender. (d) Height growth velocity curve by place of residence.

mates of growth velocity; thus, many studies used this model (12, 14, 15).

Based on our study results, weight loss occurred at least in 9.2% of children. The highest percentage of weight loss cases were related to the age of 9 to 12 months, with a prevalence of 1.7%. On the other hand, 9.3% of children younger than 2 years had at least a pause in weight growth, with a peak in children aged 4 to 6 months and with a prevalence of 2%. Furthermore, height growth pause occurred at least in 10.7% of the cases, with a peak in 4 to 6 months children with a prevalence of 1.7%.

Zayeri et al. found that growth retardation considerably decreases in the later months of child's life compared to early months (16). Kholdi et al. reported that the highest weight loss usually occurs in children aged 6 to 7 months (17). Weight loss in this age can be attributed to the beginning of complementary feeding, a reduction in passive immunity transmitted from mothers, and an increase in diarrheal diseases and other infectious diseases.

Marginal modeling in the present study indicated that the variables of child's age, residency, and multiple pregnancies, excluding breastfeeding, maternal age, maternal job, and intrauterine age have significant relationships with growth velocity. Previous longitudinal studies reported a significant association between exclusive breastfeeding and growth velocity of weight and height (14, 18-23). WHO emphasizes that inadequate feeding and diseases in childhood stage of life cycle are the leading causes of growth loss (24). Hosseini et al. reported that the mean weight is slightly higher in children who had exclusive breastfeeding compared to those who had not (14).

Another study revealed that exclusive breastfeeding has a significant relationship with growth velocity (18). Becker et al. found that child feeding in children aged 5 to 18 months has a significantly stronger association with child growth than diseases in the childhood span (25). In line with our results, several studies revealed that delayed cessation of exclusive breastfeeding is a contributing risk factor for weight loss; thus, if complementary feeding does not begin in an appropriate time, it can lead to weight loss or cessation in weight gain (19, 26). Other studies reported that deprivation of breastfeeding causes the child not to benefit from its related health, nutritional, and immunological advantages (27-29). In agreement with our findings, 2 other studies reported similar results (22, 23). However, Mohammadpoorasl et al. did not find an association between exclusive breastfeeding and child weight (26).

In the present study, we were able to find an association between child's gender and growth velocity, so that growth velocity was significantly higher in males than in females. Heydari et al. found that the mean weight and height were significantly higher in male children than in females, except for children younger than one month old (6). In line with our findings, a significantly higher velocity of growth was detected in male children compared to female children in several other studies (14) (18, 23). However, Heidari et al. did not find an association between gender and growth velocity (30). Unfortunately, cultural deprivation and social discrimination, particularly

gender-based discriminations, may result in the male children to benefit more from nutritional and other advantages of the family. In agreement with Ayatollahi et al., we obtained a significant difference between the height and weight of children who lived in rural and urban areas.

We used a longitudinal model with a large sample size; however, our study had some limitations. The most important limitation of the present study was its retrospective design in which missing data and some confounding variables were not appropriately managed.

Conclusion

With regards to our findings, the growth velocity in girls was slightly higher than in boys; however, no considerable difference was found in height growth velocity of girls compared to boys. Another important result was that the findings from this study revealed that each month increase in exclusive breast feeding leads to less growth velocity in children. Thus, exclusive breastfeeding is strongly recommended to prevent childhood obesity.

Conflict of Interests

The authors declare that they have no competing interests.

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