Child Weight Growth Trajectory and its Determinants in a Sample of Iranian Children from Birth until 2 Years of Age

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ABSTRACT

Background: Growth is one of the most important indices in child health. The best and most effective way to investigate child health is measuring the physical growth indices such as weight, height and head circumference. Among these measures, weight growth is the simplest and the most effective way to determine child growth status. Weight trend at a given age is the result of cumulative growth experience, whereas growth velocity represents what is happening at the time.

Methods: This longitudinal study was conducted among 606 children repeatedly measured from birth until 2 years of age. We used linear mixed model to analyze repeated measures and to determine factors affecting the growth trajectory. LOWESS smooth curve was used to draw velocity curves.

Results: Gender, child rank, birth status and feeding mode had a significant effect on weight trajectory. Boys had higher weight during the study. Infants with exclusive breast feeding had higher weight than other infants. Boys had higher growth velocity up to age 6 month. Breast fed infants had higher growth velocity up to 6 month, but thereafter the velocity was higher in other infants.

Conclusions: Many of the studies have investigated child growth, but most of them used cross-sectional design. In this study, we used longitudinal method to determine effective factors on weight trend in children from birth until 2-year-old. The effects of perinatal factors on further growth should be considered for prevention of growth disorders and their late complications.

Keywords: Growth, linear mixed model, velocity, weight

INTRODUCTION

Child growth is one of the important health indicators from early infancy until puberty,[1,2] such that all policymakers and staffs involved in children's health issues should be familiar with growth concepts and it's natural limits and hence that diagnoses unnatural cases, determine the causes and help child healthy.[1] Physical growth can determine the individual health status. The child with appropriate growth trajectory doesn't have nutritional disorders, chronic diseases.[3] Weight and height growth curves investigation are the most appropriate way to evaluate nutrition status and child growth.[2,4] Weight, height and head circumference are common measurements to investigate child growth. Weight is simplest and the most effective measure to determine child health.[2]

Both underweight and overweight may affect individual and society health status.[5] Underweight can be causes by diseases or social or environmental factors.[3] Underweight people are more exposed to loss energy and are prone to injury and infection.[5]

Overweight and obesity are other problems in human societies.[5-7] Studies in developing countries, Middle East and Iran imply obesity increases in childhood.[8-11] As the obesity epidemic, the prevalence of hypertension increased in children. Childhood obesity can increase the risk of adulthood obesity.[5,6,8] Obesity itself can increase the risk of disabilities of type II diabetes, hypertension, hyperlipidemia and stroke and may cause some kinds of cancer, infertility and some other problems.[6,12,13] World Health Organization in MONICA study which conducted in 1988 has reported Iran as one of the 7th countries with highest childhood obesity prevalence.[8] Breastfeeding is one of the important strategies to obesity prevention. As the length period of breastfeeding increases, the risk of obesity decreases.[7]

There are two main approaches to detecting infants with growth disorder, (1) the comparison of attained growth at a specific age with a reference chart and (2) measuring the growth indices within a time interval expressed as growth velocity.[14] Attained weight represents the cumulative growth experience that happened in the past, whereas growth velocity represents what is happening currently.[14,15] The growth velocity curve, which modeled with appropriate mathematical function, represents the best way to describe the complex patterns of weight growth during infancy and childhood.[16]

Many studies were investigated the effects of different factors on birth weight, but few surveys investigate these effects on their growth trajectory. We studied the effect of different factors on weight growth trajectory in this paper. We also represent weight growth velocity here.

Many researchers used cross-sectional design to investigate child growth. The alternative study design is to use longitudinal approach. The important characteristic in longitudinal studies is that each subject measured repeatedly over time.[17,18] The main advantage of a longitudinal study compared to a cross-sectional study is that the individual development of a certain outcome variable over time can be studied.[19,20] Longitudinal studies are also more effective and have more statistical power than cross-sectional studies.[21] When we are interested in to study changes over time, we must collect repeated measurements.[22,23] In longitudinal data that we measure subjects repeatedly over time, the observations are not independent.[20,22] Ignoring this correlation can negatively impact parameter estimation, hypothesis testing and efficiency of study design.[21] Therefore, we need special methods which can include this correlation to analysis.

METHODS

Population and setting

This longitudinal study was conducted in Isfahan, Iran, among 606 children born in 2007-2008 and followed from birth until the age of 2 years. Demographic information including gender, child rank, birth status (pre-term or full-term), parents' age, parents' education and occupation, exposure to second-hand smoke, family history of chronic diseases such as hypertension and diabetes, as well as parental obesity, were collected. The checklists were filled in by expert health professionals through the interview with one of the infant's parents. Birth weight was documented from the hospital records. Additional repeated measurements for each infant were measured and recorded by trained health staffs in 2, 4, 6, 8, 10, 12, 15, 18 and 24 month of life. Only newborns with Iranian ethnicity and without apparent congenital anomaly were enrolled to the study. Weight was measured in light clothing to the nearest 100 g. The infant's feeding method was recorded as exclusive breastfeeding or a mixed diet (including both breast and formula milk).

Sex, child rank, feeding mode, parent's age, education and occupation, number of family members, using supplement food, tobacco smoke exposure, family history of hypertension, diabetics and obesity, were investigated in this study.

Statistical analysis

In the current study, we used longitudinal design to study child weight growth. There are many statistical methods to analyze longitudinal data, but one of the most effective methods is linear mixed model (LMM)[24] effects. LMM is an extension of typical linear regression analysis which includes random effects in the structure of the mean rather than the fixed effects.[17,19,25,26] LMM was used to determine factors affecting growth trends over time.

To make weight growth velocity, we calculated weight velocities by use of the 2-pointed average weight model 2-pointed model (2-PM). 2-PM is calculated as net weight gain over the time interval (g/kg/d):

$$\text{Growth velocity} = \frac{1000 \times \left(W_{n+1} - W_{n}\right)}{\left(D_{n+1} - D_{n}\right) \times \left[\frac{W_{n+1} + W_{n}}{2}\right]}$$

In which n is measurement occasion, W_n is weight in grams on measurement "n", and W_{n+1} is weight in grams on measurement "n + 1", D_n is age in the day on measurement "n" and D_{n+1} is age in the day on measurement "n + 1".[27]

Then "LOWESS" method was used to draw weight velocity curves.[19]

We used SPSS statistical package for windows (SPSS Inc., Chicago, Illinois) version 18.0 and S-Pluse8 software (Insightful Corp, Seattle, Washington). The level of statistical significance was set at $P < 0.05$.

RESULTS

Overall, 606 infants were followed from birth up to 2 years of age. They consisted of 307 girls and 299 boys. Of newborns studied, 598 were full-term. The mean (standard deviation [SD]) of mothers' and fathers' age was 32.29 (6.33) and 37.22 (6.60) years, respectively. The mean (SD) birth weight was 3090.94 (496.20) and 3226.99 (572.78) g for girls and boys respectively. Birth weight was significantly higher in boys ($P = 0.002$). The characteristics of the study population are summarized in Table 1.

Gender ($P < 0.0001$), child rank in family, gestational age ($P = 0.005$), the type of milk consumed ($P = 0.022$) and maternal education had a significant effect on weight growth trend.

Figure 1a implies the growth curve for boys and girls. Mean weight was higher in boys from birth up to 2-year-old. This difference existed from birth time and became greater over time until 2 years of age. It means that there is interaction between sex and age. The amount of age and sex interaction was significant ($P < 0.001$).

Table 1: Demographic characteristics of the study population (n=606)

	Frequency	Percent
Gender		
Boy	299	49.3
Girl	307	50.7
Child rank in family		
1	344	56.8
2	189	31.2
≥3	73	12.0
Gestational age		
Full-term	598	98.7
Pre-term	8	1.3
Type of milk consumed		
Breastfeed	528	87.1
Mixed milks	78	12.9
Exposure to second hand smoke		
Yes	135	22.3
No	454	74.9
≤6	17	2.8
Maternal education (years)		
6-12	268	44.2
14	250	41.3
>14	88	14.5

Exclusively breast fed infants had a little higher weight, up to 12 months. Thereafter, other infants had higher mean weight. This pattern implies interaction between age and feeding mode. The amount of interaction was significant ($P = 0.044$). The weight growth curve by feeding mode is shown in Figure 1b.

As depicted in Figure 1c, although pre-term infants had lower mean weight at birth time, but this difference became smaller over time. The interaction between age and birth status was not significant. However, due to the very small number of per-term subgroup, this finding should be regarded with caution.

The interaction between age and child rank was not significant. The first child had significantly lower mean weight in comparison with the third rank and upper ($P = 0.44$). However, the difference was not significant between 1st and 2nd rank children [Figure 1d].

Maternal education was a significant predictor for the variables assessed in this study. Children of mothers with under diploma education had significantly lower mean weight than those with a diploma or higher education ($P = 0.039$).

In this study, parents' age and occupation, father education, tobacco smoke exposure and family

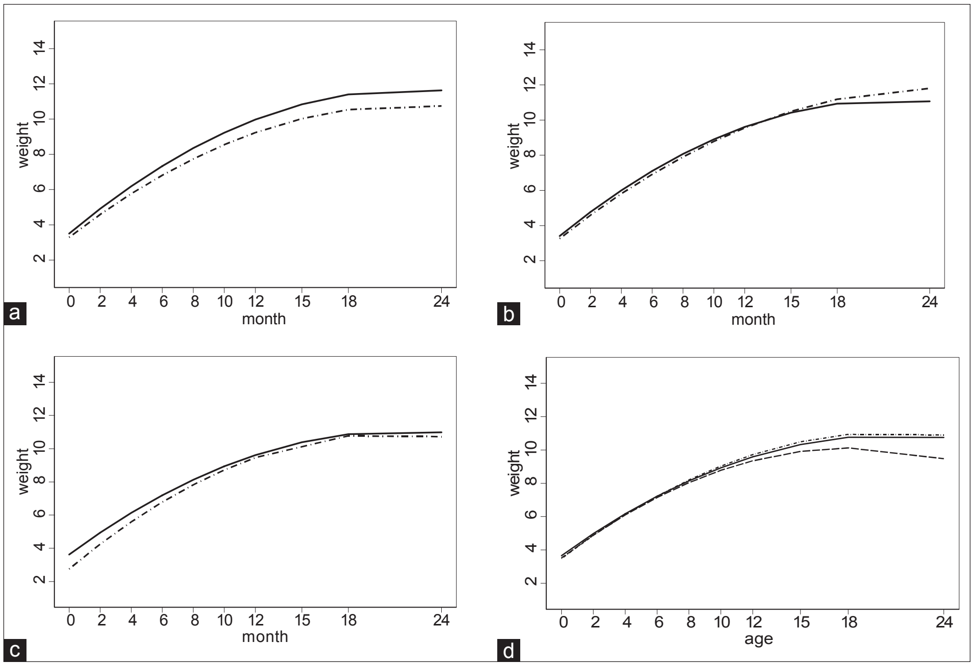

Figure 1: Weight growth trajectory: (a) Weight growth curve by gender. Solid line implies boy curve and dashed line implies girls. (b) Child growth curve by feeding mode. The solid line implies exclusive breast fed infants' curve and dashed line implies mixed milks. (c) Weight growth curve by birth status. Solid line implies full-term infants and dashed line implies pre-term. (d) Weight growth curve by child rank in family. Solid line, dotted line and dashed line imply first, second and third and upper rank respectively

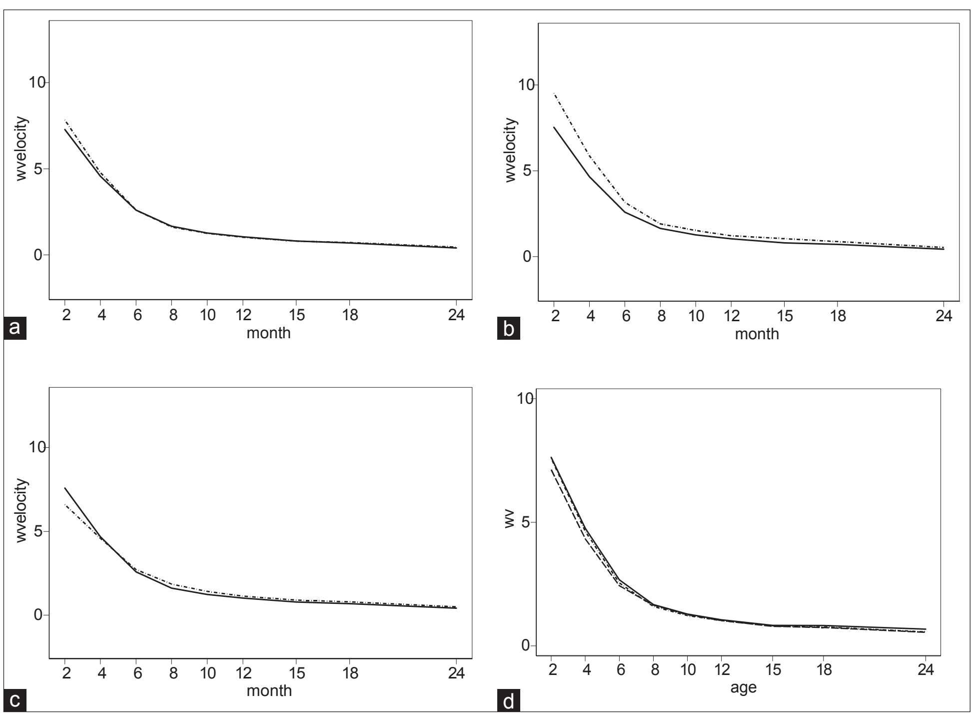

Figure 2: Weight velocity curves: (a) Weight velocity curve by sex. Girls curve is in solid and boys curve is in dashed line. (b) Weight velocity curve by birth status. Solid line implies full-term and dashed line implies pre-term infants. (c) Weight velocity curves by feeding mode. Solid line implies breast fed and dashed line implies mixed fed infants. (d) Weight velocity curves by child rank in family. The curves of first and second rank are matched and they can see as a solid line. Dashed line implies third rank and upper

history of hypertension, diabetes and obesity did not have statistically significant effect on the trend of weight gain.

Regression coefficients of the final model for weight are presented in Table 2.

To investigate weight growth velocity, we used "LOWESS" curve. Figure 2a implies weight velocity curves by gender. It shows that boys had higher growth velocity at the beginning and then their velocity came closer to that of girl's. Figure 2b demonstrates that at birth time, pre-term infants had very higher velocity than their full-term counterparts; and it became close to full-term velocity curve up to 2 years of age.

Figure 2c implies weight growth velocity by feeding mode; It shows that breast fed infants had higher velocity early at birth time. Then it became close to mixed fed infants and after 6 months, they had lower velocity. Weight growth velocity by child rank is shown in Figure 2d.

DISCUSSION

Growth is a very important event in childhood. Many researchers have investigated child growth, but most of them used a cross-sectional design for their study. In the current study, we used longitudinal data to study weight trajectory from birth. Longitudinal studies have major advantages in comparison with cross-sectional surveys. We implemented LMM for longitudinal data, so we were able to examine a wide range of factors that might affect changes in weight-for-age during the first 2 years of the child's life.

Infant gender, child rank, birth status (gestational age), maternal education and feeding mode (breast or mixed feeding), affected the weight changes in this period. Factors as parental age and occupation and father education were not associated with the trend of weight change over time.

Raum *et al*. in an article 2011, studied 1418 infants with both cross-sectional and longitudinal methods, and used LMM to analyze longitudinal data.[28] Karaolis-Danckert *et al*. in 2008 used mixed models to determine the relationship between weight velocity and body fat percent.[29] Regnault *et al*. has modeled the growth by using mixed model.[30] Heydari in 2009 used a longitudinal method to study weight and height growth in child under 2 years of age.[31]

Table 2: Model coefficients of weight growth

Variable	Estimate	Standard error	df	*t* value	Lower	Upper	*P* value
Intercept	2.86	0.232	3366	12.31	2.41	3.32	<0.0001
Age	0.73	0.008	3366	96.02	0.71	0.74	<0.0001
I (age^2)	−0.02	0.0003	3366	−54.37	−0.0167	−0.0161	<0.0001
Gender							
Girl	−0.26	0.056	598	−4.54	−3.67	−0.15	<0.0001
Boy	-	-	-	-			-
Child rank							
Third and upper	0.23	0.087	598	2.63	0.06	0.40	0.009
Second	0.15	0.061	598	2.51	0.03	0.27	0.013
First	-	-	-	-	-	-	-
Gestational age							
Full-term	0.67	0.23	598	2.91	0.22	1.12	0.004
Pre-term	-	-	-	-	-	-	-
Feeding mode							
Breast fed	-	-	-	-	-	-	-
Mixed diet	−0.27	0.117	598	−2.30	−0.50	−0.04	0.022
Maternal education							
6-12	−0.12	0.059	598	−2.07	−0.24	−0.01	0.039
14	0.03	0.081	598	0.33	−0.13	0.19	0.741
>14 years	-	-	-	-	-	-	-
Age: Gender	−0.04	0.007	3366	−5.13	−0.05	−0.02	<0.0001
Age: Feeding mode	0.04	0.015	3366	2.83	0.01	0.07	0.005

P value<0.05 is significant

Gender had a significant effect on weight growth trend, such that boys had higher mean weight from birth up to 2 years of age. In the study of Regnault *et al*. in 2010, boys were heavier than girls at birth time and they had higher weight velocity in 1 and 3 month of life.[30] Heydari *et al*. in 2005 studied 597 infants from birth to 2-year-old. In their study, boys mean weight was higher than girls, except for 1st month. But the mean weight difference between the boy and girl was not statistically significant before month 2 and at year 2.[32]

In our study, maternal education had a significant effect on weight growth trend; such that the birth weight of mothers with education lower than 14 years had significantly lower than children of mothers with higher education. In Raum *et al*. study, mother's education was significant before adjustment with other variables, but after adjustment it did not have a significant effect.[28] In another study, illiteracy of mothers was documented as a risk factor for child underweight.[33]

The family history of hypertension, diabetes and obesity did not have a significant effect on the child weight growth trend. In the study of Kalantari *et al*., family history of overweight and obesity had a significant effect on obesity in children.[7] In the study of Regnault *et al*., maternal obesity had a significant effect on birth weight, but this relationship was not significant at months 1 and 3 and paternal obesity did not have a significant effect on birth weight.[30]

Many studies documented maternal smoking during pregnancy as a risk factor of low birth weight and future obesity in their children. Raum *et al*. and Karaolis-Danckert *et al*. implied that smoking before and after pregnancy increases the risk of obesity in children.[28,29] In another study, the infants of a mother who smoked a cigarette during pregnancy had lower weight between births up to 3th month.[30] In our study, the effect of exposure to tobacco smoke was not significant on weight change trend. Likewise, it did not have any significant effect on birth weight.

In our study, exclusive breast fed infants had a little higher mean weight before the age of 12 months; however after this time, mixed diet infants had higher mean weight. This trend can implies the higher risk of childhood obesity in infants fed with other types of milk. Our findings are consistent with some previous studies. Kelishadi *et al*. in 2005 observed that the frequency and duration of breast feed was lower in obese children.[34] Raum *et al*. showed that breast feeding decrease child obesity risk in 6-year-old children.[28]

In our study, the child rank in the family had a significant effect on the weight growth trend. This finding is in line with some previous studies in showing that firstborn children may be smaller than their counterparts.[30] Karaolis-Danckert *et al*. implied that being the first child of the family may increase the risk of childhood obesity.[29] However in the study of Raum *et al*., the birth rank had no significant effect on future overweight.[28]

In the present study, the growth pattern of preterm newborns was significantly different from their full-term counterparts, but as described before, the result should be regarded with caution because the number of pre-term infants was much smaller than full-term babies.

We used the 2-pointed weight model to make velocity curves. Many studies used this model to make weight velocity.[14,27] As Patel *et al*. implied, 2-pointed model provided an accurate estimate of growth velocity.[27]

The effects of early life growth and incidence of diseases in later life have been studied in many studies.[35-39]

Determining factors affecting early growth can be useful in policy making for prevention of short-term and long-term complications of growth disorders.

CONCLUSIONS

Given the long-term squeals of growth disorders and the documented effects of early life factors on further growth, primordial preventive measures should be considered for the modifiable factors affecting the child growth.

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