Short Communication

The effect of breastfeeding on children's growth indices up to 6 months: An application of multivariate t linear mixed model

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Background: This study aimed to determine the effect of breastfeeding on children's growth indices. **Materials and Methods:** Longitudinal data of children's growth (height, weight, and head circumference) were as a dependent variable and type of nutrition as an independent variable with using multivariate t linear mixed model. **Results:** The indicated that the height, weight, and head circumference of infants who were fed with breast milk showed a statistically significant difference ($P < 0.05$) with those of infants receiving formula. **Conclusion:** Exclusive feeding with breast milk, especially in the first 6 months of life, has a significant impact on the child's growth indicators compared to formula or, or a combination of both.

Key words: Growth, longitudinal data, multivariate t distribution

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INTRODUCTION

In the first 6 months of a baby's life, breast milk provides all the nutrients necessary for survival, growth, as well as protection against possible infections and boosting body's immune system.[1] The World Health Organization and UNICEF recommend that infants be exclusively breastfed for the first 6 months of life, i.e., receive no other food or fluids, including water.[2] Moreover, its continuation up to 2 years of age with complementary feeding has been recommended.[3] Previous studies show that the use of mother's milk alone in the first 3 months of a child's life leads to favorable growth, and after that, the child will better grow by receiving complementary foods.[4] Accordingly, in this article, we intend to investigate the effect of the type of nutrition in children under 1 year of age, including breastfeeding, formula, or a combination of both, on children's growth indicators (height, weight, and head circumference), using multivariate t linear mixed statistical model. The proposed model has a better performance compared to other competing models due to considering the correlation between longitudinal data.[5] Since longitudinal data are abundantly available to medical researchers, this model with a developed algorithm can be easily used in medical science data.

METHODS

Study design

We used a prospective method and longitudinal data. The statistical population of this study consisted of a sample of 250 pair infants–mothers who were referred to health centers in Ahvaz (southwest of Iran) to monitor their anthropometric indices, using cluster sampling. Informed consent was obtained from the parents of

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the children participating in the study. The ethics code IR.SRBIAU.REC.1398.5 was registered at the university. A total of 750 samples were collected for subsequent analysis.

Variable assessment

Infants were divided into three groups based on the type of nutrition. The first group was exclusively breastfed, the second group was fed with formula, and the third group with both breast milk and formula (combined). Linear growth and correlation between study variables were included in the statistical model.

Statistical analysis

Using the mean and standard deviation, first, we attempted to describe the quantitative variables of the study, i.e., children's growth indicators (height, weight, and head circumference) from birth to 12 months. Then, in the inferential part of the study, we estimated the regression parameters of linear mixed model of t distribution and normal distribution. The data were analyzed with (R) software package, version 4.0.2 2 (Ross Ihaka and Robert Gentleman, Aukland, North Island, New Zealand).

Statistical method

X is a dependent variable over time, as for the variable of birth weight, birth height, and birth head circumference, we define Three variables longitudinal data X_{ij1}, X_{ij2}, X_{ij3}. Respectively where, I = 1, 2,…, 250 shows the number of infants participating and j = 1,…,6 is Number of months monitoring infant growth.

The multivariate linear mixed model, in which we fit the t distribution to the data, is called multivariate t linear mixed model for short, and we define its as follows:

$$f\left(x;\mu,\Omega,\nu\right)=\frac{\Gamma\left(\left(\nu+a\right)/2\right)\left|\Omega\right|^{-1/2}}{\Gamma\left(\nu/2\right)\left(\pi\nu\right)\alpha/2}$$
$$\left(1+\frac{\left(y-\mu\right)^{T}\Omega^{-1}\left(y-\mu\right)}{\nu}\right)^{-\left(\nu+a\right)/2},\ x\in R^{a} \quad (1)$$

RESULTS

Of 250 infants participating in the study, on average, 80.36% were breastfed, 10.37% were fed with formula, and 9.38% a combination of both. Of all the participants, 125 (50%) were boys and 125 (50%) were girls. The mean birth weight of the study infants who were breastfed is equal to 35200 kg (±400); the mean birth height was 49.1 cm (±1.8); and the mean birth head circumference was 41.37 (±1.4). Infant gender and birth weight were effective in weight gain of the baby ($P<0.001$) [Table 1]. It also shows infant's growth information according to the type of nutrition received that mean growth of height, weight, and head circumference of infants with exclusive breastfeeding is higher than the other two groups. Furthermore, the mean height, weight, and head circumference of children who use combination of both milks were higher than children who use only formula milk. Table 2 shows the estimation of the model parameters using with multivariate regression with two statistical models, multivariate mixed t distribution, and multivariate mixed normal distribution for the three dependent variables (infant's weight, height, and head circumference). The height, weight, and head circumference of infants who were fed with breast milk showed a statistically significant difference ($P<0.05$) with those of infants receiving formula: infants receiving breast milk were taller ($P = 0.0002$) and heavier ($P<0.001$) and larger head circumference ($P=0.002$) than infants receiving formula. Infants that were breastfed had a better growth than those that were formula fed and had combined feeding.

DISCUSSION

In this article, the multivariate mixed t distribution considers the existing correlation between longitudinal data well and can therefore be used in many medical and paramedical fields where longitudinal data are abundantly used.

Given that exclusive breastfeeding is not just a lifestyle but an investment in children's health,[6] in this study, The statistical model showed that infants who were breastfed had better growth in terms of weight, height and head circumference than infants who received formula or a

Table 1: Mean and standard deviation of weight, height, and head circumference

	Mean±SD					
	Time of birth	2 months	4 months	6 months	8 months	12 months
Weight (kg)	3.52±0.48	5.15±0.67	7.14±0.82	8.23±0.97	9.38±0.11	10.43±0.60
Height (cm)	50.85±1.85	56.27±2.50	63.21±2.71	67.21±2.74	72.45±2.81	76.00±2.68
Head (cm)	35.10±1.43	38.10±1.31	41.29±1.39	42.99±1.29	44.82±1.50	45.98±1.46
	Breastfed		Formula-fed		Both milk types	
Birth weight (kg)	3.52±0.4		3.35±0.5		3.51±0.5	
Birth height (cm)	49.1±1.8		48.8±1.7		48.9±1.9	
Birth head circumference (cm)	41.37±1.4		41.29±1.2		41.87±1.1	

SD=Standard deviation

Table 2: Estimation of the coefficients in a three-variable regression model based on multivariate t linear mixed model and multivariate normal linear mixed model

	Coefficients	MtLMM	SD	*P*	95% confidence limits	
Height						
Time (month)	B01	2.7614	0.0906	0.002572	2.750169	2.772631
Breastfed	B11	44.5322	0.084	0.002384	44.52179	44.54261
Both milk	B21	44.8944	0.0834	0.002372	44.88406	44.90474
Formula-fed			Reference level			
Weight						
Time (month)	B02	877.8012	0.0005	0.003116	877.8011	877.8013
Breastfed	B12	76.9934	0.0005	0.002768	76.99334	76.99346
Both milk	B22	17.5501	0.0005	0.002832	17.55004	17.55016
Formula-fed			Reference level			
Head circumference						
Time (month)	B03	1.4022	0.1573	0.002496	1.3827	1.4217
Breastfed	B13	30.3182	0.1413	0.002384	30.30068	30.33572
Both milk	B23	30.4658	0.1401	0.002404	30.44843	30.48317
Formula-fed			Reference level			
	Coefficients	**MNLMM**	**SD**	***P***	**95% confidence limits**	
Height						
Time (month)	B01	2.1451	0.1703	0.002944	2.123989	2.166211
Breastfed	B11	50.577	0.2136	0.003164	50.55052	50.60348
Both milk	B21	50.4255	0.1962	0.003180	50.40118	50.44982
Formula-fed			Reference level			
Weight						
Time (month)	B02	718.3082	0.0006	0.002816	718.3081	718.3083
Breastfed	B12	59.1536	0.0008	0.002960	59.1535	59.1537
Both milk	B22	11.4014	0.0007	0.003180	11.40131	11.40149
Formula-fed			Reference level			
Head circumference						
Time (month)	B03	0.9564	0.379	0.002916	0.909418	1.003382
Breastfed	B13	34.5712	0.5267	0.002968	34.50591	34.63649
Both milk	B23	34.328	0.4615	0.002968	34.27079	34.38521
Formula-fed			Reference level			

MtLMM=Multivariate t linear mixed model; MNLMM=Multivariate normal linear mixed model; SD=Standard deviation

combination of both. Proper nutrition plays a vital role in achieving optimal growth and development. A study in Ethiopia (2021) shows that, compared to formula feeding, continuation of breastfeeding alone results in infant's short stature, thus pointing to the necessity of complementary feeding after 6 months of age. The study also indicates that female babies benefit from breast milk more than boys. It may be thought that breast milk alone does not meet the nutritional needs of baby boys, and that is why the use of complementary feeding should be started earlier for these infants.[7] Several studies have been conducted by Kramer *et al*. on the effects of nutrition on children's growth which show that exclusively breastfed infants are taller and heavier than formula-fed infants up to 9 months of age and grow better than other infants at 3–6 months. However, these studies show no statistically significant difference in the size of their head circumference.[8-10]

In most studies on the effects of nutrition on infant growth up to 12 months, cross-sectional analyses at various intervals have been done without considering the correlation between longitudinal data, where the growth indices were considered as unilabiate, and no significant relationship was observed between them. However, the model used in the present study was able to consider the correlation between longitudinal data and anthropometric indices of height, weight, and head circumference: an ability which is considered a special advantage compared to existing analyzing methods This study shows that medical researchers can further evaluate and analyze these types of models in the longitudinal data collected at different times of the treatment stages of patients and considering the correlation between variables.

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Conflicts of interest

There are no conflicts of interest.

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