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Analysis of Repeated Measures of Weight of Children under Five Years, A Comperative Analysis between Male and Female Children (CASE STUDY: Tamale Metropolis)

Tuahiru Maahi[1], Abdul-Rahaman Haadi[2]

[1]Department of Statistics, Mathematics and Science, Tamale Polytechnic, P. O. Box 3 Education Ridge, Tamale - Ghana E-mail: maahituahiru@yahoo.com
[2]Department of Statistics, Mathematics and Science, Tamale Polytechnic, P. O. Box 293 Education Ridge, Tamale – Ghana E-mail: masetripple@yahoo.co.uk

Abstract: This paper seeks to describe the use of several methods to analyze repeated measure using data collected on weight of children under five years of age at the weighing centers in Tamale metropolis in the northern region. The question of interest is to find out if there is a change in mean weight gain by children under five year over time and if the factors (age, feeding type, feeding practice gender etc) influence those changes. The data was collected from 210 children put into three groups of ages 0-6 months, 7-12 months and 13-18 months on monthly bases for a total of 1260 observations. Three feeding types: exclusive breast feeding, breast feeding with introduction of plumpy nut food supplement and completely complementary feeding. Univariate ANOVA and multivariate MANOVA techniques were use to analyzed the data. Both random effect and fixed effect models shown to be better for the data. Age, feeding type and feeding practices were the factors that did not support the null hypothesis and therefore influencing the children weight gain with the p-values of <0.001 at 5% level in all the three cases.

Keywords: Repeated measures, longitudinal data, feeding types, Anova, Manova.

Introduction

Repeated measures data are encountered in a wide variety of disciplines, including business, behavioral science, agriculture, ecology, and geology. What distinguishes repeated measures data from time series data is that multiple subjects are involved in the former, and the number of measurements per subject is generally not very large.

When several measurements are taken on the same experimental unit (e.g. involving persons, animals, or machines), the measurements tend to be correlated with each other. When the measurements represent qualitatively different things, such as weights, lengths, and widths, the correlation is best taken into account by the use of multivariate methods, such as Multivariate Analysis of Variance (MANOVA).

MANOVAis a technique that measures the differences of two or more metric dependent variables based on a set of categorical (nonmetric) variables acting as independent variables. When the measurements represent responses to treatments or levels of the experimental factor of interest, such as time, the correlation can best be accounted for by performing a repeated measures analysis of variance.

An experimental design that accommodates this type of measurement is the repeated measures design. A repeated measures design refers to studies in which the same measures are collected a multiple of times for each subject, but under different conditions.

A popular repeated-measures design is a crossover study defined as a longitudinal study in which subjects receive a sequence of different treatments (or exposures). Many important crossover studies are controlled experiments, even though they are observational studies in nature.

Methodology

The data for the analysis of the study was obtained from four weighing centers selected in the Tamale metropolis, namely the Tamale Teaching Hospital, the Choggu Weighing Center, Sakasaka Community Nursing Training School and the Kpalsi South Polyclinic. The data was collected on weights of children between zero (0) to eighteen (18) months old, in six (6) months period indicating their sex, marital status of mothers, mothers age, infants feeding practice used by mothers, socio-economic background of parents and the educational level of the mother.

Abdul-Rahaman Haadi (Correspondence)
masetripple@yahoo.co.uk
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Multivariate data analysis (MANOVA) was employed as the main statistical tool for analyzing the data. The months are the subjects (levels or treatments) and the factor "TIME" and "GENDER" (male and female) are the group. Interest will be on between-subject effect (such as GROUP), within-subject effect (such as TIME) and the interactions between the two types of effects (GROUP × TIME). Also regression analysis will be considered. The response variable in the regression analysis is infant weight gain of the children with other factors (sex of the child, mother education level, marital status of the mother, child feeding practice among others) as the predictor variables for the model.

Results and Discussions

Table 4.1 presents the snapshot of the data used for the analysis. It was collected from two hundred and ten (210) children less than five years of which 70 were at exclusively breastfeeding stage (0-6 months), 70 breastfeeding with Plumpy nut food (7-12 months) and 70 children between the age's of13-18 months who were on complementary feeding.

The repeated weighing records for the six months are shown in columns 9 – 13 respectively. In the data there were three feeding type studied;

i) Exclusive breastfeeding represented by the number 1
ii) Breastfeeding with the introduction of Plumpy nut food supplements represented by the number 2
iii) Complementary feeding group represented by the number 3

Row 1 to row 70 contained data for the children with ages 0 – 6 months old, rows 71 to 140 represents those of ages 7 – 12 months old and the rest of the seventy rows were the ages 13 – 18 months. Equal group sizes were used to satisfy the assumption of group equal in repeated measure analysis. All the three feeding groups were included in the analysis to examine weight change within them in the study period.

Table 4.1Snapshot of the Data Used For the Analysis

ID	Age	Sex	posi	sib	Occ	Feed	prac	W1	W2	W3	W4	W5	W6
1	1	2	1	1	3	1	1	3.0	4.0	4.5	4.4	4.5	5.0
2	1	2	1	1	3	1	1	3.2	4.5	5.6	6.6	6.7	6.9
3	1	1	4	3	2	1	1	2.8	5.3	6.0	7.0	6.9	7.5
4	1	2	3	3	3	1	1	4.8	5.5	6.0	6.2	6.6	6.7
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	2	2	2	2	1	2	2	5.0	6.2	6.0	6.2	6.5	6.7
72	2	1	3	3	1	2	2	4.4	5.1	5.5	6.0	6.2	5.8
73	2	1	2	2	1	2	2	6.0	6.3	5.9	6.8	7.3	7.2
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
207	3	1	1	1	2	3	2	8.0	8.2	8.8	9.0	9.5	10.0
208	3	1	1	1	2	3	2	5.1	5.8	6.0	6.5	7.0	7.0
209	3	1	2	1	3	3	2	6.5	6.5	7.1	7.3	8.6	8.0
210	3	1	3	2	2	3	2	8.5	8.5	9.0	9.7	10.2	10.8

Profile plot of mean responses in repeated measurement analysis can be very useful as they provide a good basis for selecting suitable models for the data set. Figure 4.1 displays a plot of the mean weight gain at each month for each age group.

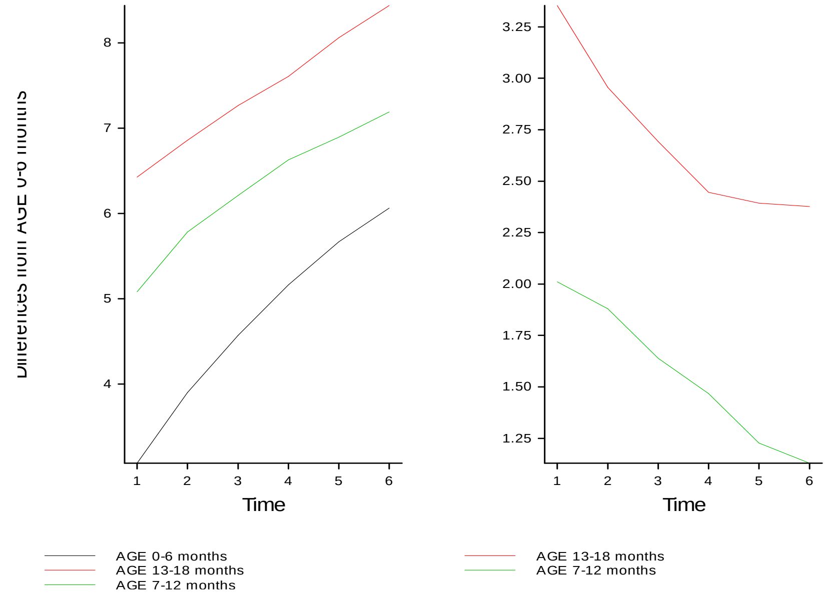

Figure 4.1 Mean Weight Gain for Age Groups at Each Month

Measuring the differences in mean response over time is more like measuring within individual weight change of the children (Fitzmaurice, laird, and ware, 2004). From the figure it can be deduced that the mean weight of the age group 0-6 months grew faster than the other two age groups even though there were all increasing over the time period.

Figure 4.2 also shows a plot of the mean weight gain at each month for each of the three feeding types.

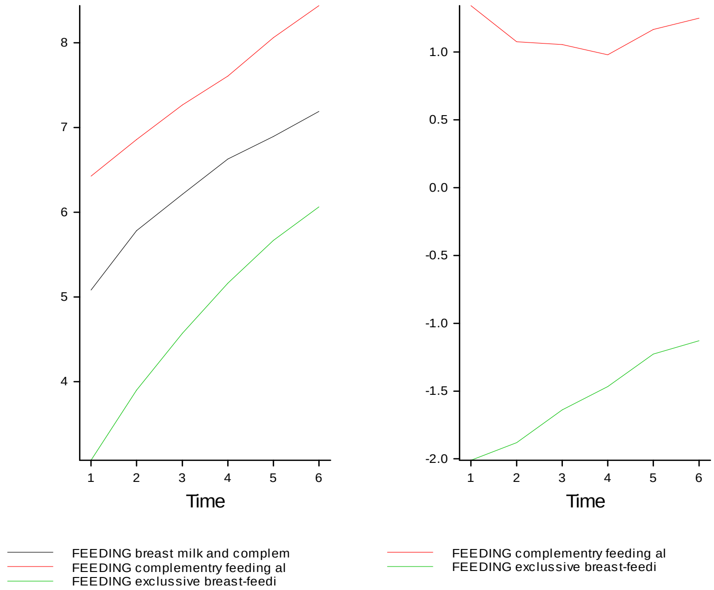

Figure 4.2 Mean Weight Gain for the Feeding Types at Each Month

The three groups realized a different rate of increase in weight gain from the start of observation to the end. The observation in this is similar to the age group observation made above. This may be because the three age groups where fed with different food types. The graph also suggest a within feeding type difference over the six months period.

The mean weight gain at the various months for gender was also plotted as shown in figure 4.4. The black line represents female while the red line represents male.

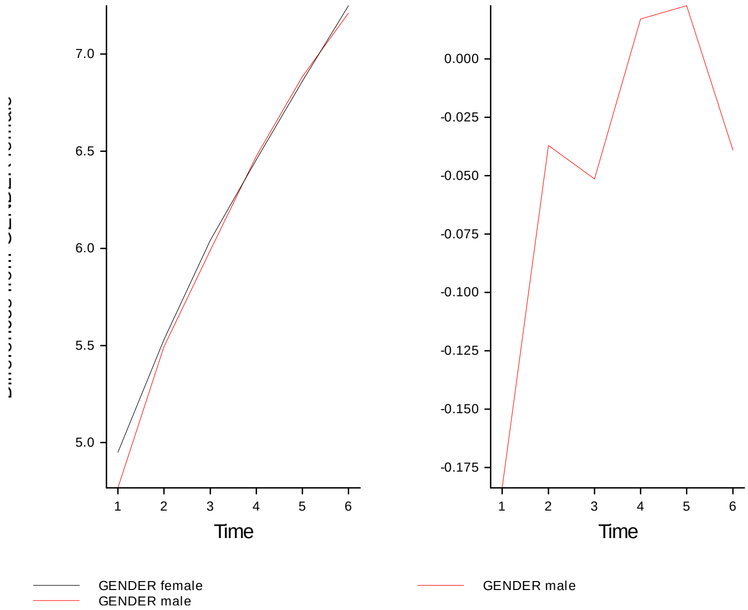

Figure 4.4 Mean Weight Gain for Gender at Each Month

The graph shows female children growing at a rate slightly higher than their male counterpart at the beginning up to month 3 and slightly lower than the male children after the month 5. In general the mean weight gain was similar for gender over the study period.

To achieve the set objectives of the study, repeated-measures analysis of variance techniques were used for the analysis with the response variable been the weight of the children. There are two main options used in the analysis of repeated measurement from a given subject;
Option 1: Using Repeated-Measures ANOVA, the Univariate approach. This option has restrictive assumptions.

Option 2: Using Repeated-Measures MANOVA, the Multivariate approach. This approach has less restrictive assumptions.

The tests were done with the level of significance of 5% (CI = 95%). The results from the various analyses performed was obtained using IBMSPSS software package.

The table 4.2a and 4.2b shows the print out of the between subjects effect and the within subject effect of the model. The tables are made up of six columns each. The source of variation column, the degree of freedom column, sum square column, mean square column, expected mean square and the p-value columns

Table 4.2a Univariate Analysis of variance for between Subject Effects

Test of Hypotheses for Between Subject Effects					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Subject stratum					
AGE	2	1546.4401	773.2201	136.26	<.001
Residual	207	1174.6069	5.6744	29.08	
Total	209				

The above results show that age is significant. This means that the hypothesis that the weight gain by age groups is the same over the time period would be rejected. Weight of a child therefore changes as he or she grows from one month to the other.

With the Subject.Time stratum degree of freedom correction factor of 0.4988, the model produces results as shown below

Table 4.2b Univariate Analysis of variance for within Subject Effects

UnivariateTest of Hypotheses for Within Subject Effects					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Subject.Time stratum d.f. correction factor 0.4988					
Time	5	814.9137	162.9827	835.29	<.001
Time.AGE	10	34.1982	3.4198	17.53	<.001
Residual	1035	201.9498	0.1951		
Total	1259	3772.1087			

The hypothesis for the age groups by time interaction is also significant since the hypothesis that the interaction has no effect on weight gain produces a p – value <.001. It can therefore be concluded that the effect of both time and age is significant on weight gain by the children.

In table 4.3a and 4.3b, the repeated measure ANOVA results for the dependent variable (weight gain by children) by feeding type as independent variable is also presented respectively for the within and between subjects effects.

Table 4.3a Test of Hypotheses for Between Subject Effects

Test of Hypotheses for Between Subject Effects					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Subject stratum					
FEEDING	2	1546.4401	773.2201	136.26	<.001
Residual	207	1174.6069	5.6744	29.08	
Total					

The between feeding effect test in the above table produces a p-value of < .001. This does not support the hypothesis of equal mean effects. Therefore the test for feeding type is also significant.

Table 4.3b Univariate Analysis of variance for within Subject Effects

UnivariateTest of Hypotheses for Within Subject Effects					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**

Subject.Time stratum d.f. correction factor 0.4988					
Time	5	814.9137	162.9827	835.29	<.001
Time.FEEDING	10	34.1982	3.4198	17.53	<.001
Residual	1035	201.9498	0.1951		
Total	1259	3772.1087			

In the within subject effect test above it is shown that feeding type by time interactions is significant at $\alpha = 0.05$ significance level with p-values 0.001

To perform the comparism test between male and female weight gain at the childhood level using the univariate analysis of variance model stated above, table 4.4a produce the results for the dependent variable (weight gain) by the independent variable (gender). The results shows that the between subject (gender) effect is not significant. This is because the p – value generated for the analysis is 0.825 greater than the α = 0.05 level of significance.

Table 4.4a Analysis Of Variance Table for Gender

Test of Hypotheses for Between Subject Effects

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Subject stratum					
GENDER	1	0.6446	0.6446	0.05	0.825
Residual	208	2720.4023	13.0789	57.96	
TOTAL					

Therefore we fail to reject the hypothesis that the mean weight gain is the same for the six months. Sex is not an influencing factor on growth at the infant level.

Table 4.4b Univariate Analysis of variance for within Subject Effects

Univariate Test of Hypotheses for Within Subject Effects

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Subject.Time stratum d.f. correction factor 0.4473					
Time	5	814.9137	162.9827	722.25	<.001
Time.GENDER	5	1.4633	0.2927	1.30	0.275
Residual	1040	234.6847	0.2257		
Total	1259	3772.1087			

In table 4.4b the test present in-significant test for the gender by time interaction at 5% with the p – value of 0.275. It can therefore be concluded that the effect of both time and gender is not significant on weight gain by the children.

Below is the analysis of the treatment or interaction effects for each factor in the study area. There is a table for each factor. For each time point, there was a test for an effect at that time point, and another for an effect in all the data up to that time. The first column is the time with the statistic, degrees of freedom and its probabilities respectively for the test for an effect at that time point while the rest of three columns are for effect in all the data up to that time for age factor. Table 4.5 present the information.

Table 4.5 Tests Of AGE Assuming Ante-Dependence Structure Of Order 5

Time	Statistics	d.f.	Probability	Statistics	d.f.	Probability
1	213.221	2	<0.001	213.221	2	<0.001
2	2.569	2	0.277	215.280	4	<0.001
3	2.944	2	0.229	217.715	6	<0.001
4	0.355	2	0.837	217.541	8	<0.001
5	10.666	2	0.005	227.779	10	<0.001
6	6.897	2	0.032	234.200	12	<0.001

It can be seen in table 4.5 that, for age factor, an effect has appeared at the first month and also at the fifth month and above. No effect was realized from month three and month four. The overall test statistic using all the data set from all the time point for the three different age groups was 234.200 at 12 degrees of freedom show a significant effect with a probability of 0.001 at the 0.05 significance level.

The feeding type by each time effect test shows similar results to that of the age groups above. The effects of the treatment were seen at the 1st month, the 5thmonth and the 6th month. There was no effect produce in the 2nd up to the 4th months. The overall test statistic of 234.200 at 12 degrees of freedom using all the data set from all the time point for the three different feeding groups also have a significant effect with a probability of 0.001 at the 0.05 significance level. Table 4.6in appendix A presents the distribution.

The gender ante dependence analysis shows a different analysis from that of age and feeding type. There was no effect of the treatment in all the months for the six months period. The overall test using all the data set from all the time point for the two gender levels was not significant since the overall test statistic as 6.699 at 6 degrees of freedom with the p-values of 0.350 far greater than 0.05. Table 4.4shows the print out.

Table 4.7 Test for Change at Each Time and Overall Test Up To Each Time

Time	Statistic	d.f.	Probability	Statistic	d.f.	Probability
1	0.594	1	0.441	0.594	1	0.441
2	3.111	1	0.078	3.711	2	0.156
3	0.250	1	0.617	3.954	3	0.267
4	1.263	1	0.261	5.216	4	0.266
5	0.062	1	0.803	5.267	5	0.384
6	1.428	1	0.232	6.699	6	0.350

At this stage of the analysis, other factors like feeding practice, birth position on the child, number of siblings living with the child and mothers occupation are considered leading to a multivariate analysis of the repeated measure analysis.

Using the output in table 4.9 the standard definition for the extremes are shown for the factors. The table contains seven columns and six rows. The effects of the factors are in the first column, the extremes for each factor is in column two, the values of the extremes in column three and *F* values in column four. Hypothesis degrees of freedom, error degrees of freedom and the significance are in column five, six, and seven respectively.

Table 4.9 Multivariate Repeated Measure Analysis on Weight Gain

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.919	303.776	6.000	161.000	.000
	Wilks' Lambda	.081	303.776	6.000	161.000	.000
	Hotelling's Trace	11.321	303.776	6.000	161.000	.000
	Roy's Largest Root	11.321	303.776	6.000	161.000	.000
practice	Pillai's Trace	.356	5.840	12.000	324.000	.000
	Wilks' Lambda	.670	5.958	12.000	322.000	.000
	Hotelling's Trace	.456	6.075	12.000	320.000	.000
	Roy's Largest Root	.347	9.361	6.000	162.000	.000

Position	Pillai's Trace	.181	1.748	18.000	489.000	.029
	Wilks' Lambda	.828	1.752	18.000	455.862	.029
	Hotelling's Trace	.198	1.753	18.000	479.000	.028
	Roy's Largest Root	.121	3.297	6.000	163.000	.004
siblings	Pillai's Trace	.084	1.181	12.000	324.000	.296
	Wilks' Lambda	.918	1.176	12.000	322.000	.299
	Hotelling's Trace	.088	1.171	12.000	320.000	.303
	Roy's Largest Root	.058	1.570	6.000	162.000	.159
occupation	Pillai's Trace	.061	.847	12.000	324.000	.602
	Wilks' Lambda	.940	.846	12.000	322.000	.602
	Hotelling's Trace	.063	.845	12.000	320.000	.603
	Roy's Largest Root	.050	1.351	6.000	162.000	.238

The table shows that only the feeding practice is an influential factor in determining the weight gain of children less than five years. This is with the fact that the p-value for all the extreme measures is 0.000 at 5% significance level. This means that factors such as position of birth, number of sibling and mothers qualification do not directly influencing growth at the infant level.

To estimate the covariance structure define for the random model, the restricted maximum likelihood variance component analysis was conducted. Table 4.10 present the results. The first part looked at the covariance structure define for the random model and the second part looked at the residual variance model. The restricted maximum likelihood analysis above present the covariance structure defined for the random model. The analysis estimated the Sigma2 which is the total variance for the experiment to be 1.108. Therefore the whole plot error variance can be determine by finding the product of the total variance (Sigma2) and the value of the theta1 which is 0.8240. That is $1.108 \times 0.8240 = 0.9130$

Table 4.10REML Variance Components Analysis

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No.rows
subject._Time	subject	Identity	1	210
	Time	Uniform	1	6

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	S.e.
$Subject \bullet Time$			Sigma2	1.108	0.093
	subject	Identity	-	-	-
	Time	Uniform	theta1	0.8240	0.0162

Gender variance component analysis estimated the Sigma2 (the total variance) to be 2.368 and the theta1 as 0.9047. Therefore the whole –plot error variance can also be determine by finding the product of the total variance (Sigma2) and the value of the theta1 which is 0.9047. That is $2.368 \times 0.9047 = 2.1423$

Table 4.11 below shows the output of the ANOVA for the Wald test for fixed effect. The table contained five columns representing the fixed term, Wald statistic degree of freedoms, Wald mean sum of squares and the chi-square probabilities. In the table we realized that all the three terms (time, age and the interaction between the time and the age) in the fixed model are significant with p-values 0.001.

Table 4.11 Wald Test for Fixed Effect

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sqprob
Sequentially adding terms to fixed model				
Time	4176.46	5	835.29	<0.001
AGE	272.53	2	136.26	<0.001
Time.AGE	175.27	10	17.53	<0.001
Dropping individual terms from full fixed model				
Time.AGE	175.27	10	17.53	<0.001

To find out the relationship between monthly mean weight gain and factors such as position of child to the mother, number of siblings living with the child, mother's occupation and child feeding practice in the house, multiple regression analysis was performed. Table 4.13 contains the output of the regression analysis of variance.

Table 4.13Regression ANOVA Output

Model		S S	Df	M S	F	Sig.
1	Regression	72.381	4	18.095	10.055	.000[a]
	Residual	368.940	205	1.800		
	Total	441.321	209			

a. Predictors: (Constant), Feeding practice of child, Number of siblings to the child, Occupation of mother, position of child to the mother
b. Dependent Variable: mean weight

From the table, it can be deduced that the model is significant with F-value of 10.055 at p-value of 0.00. The factor that contributed significantly to the weight gain was the feeding practice in the house. Number of siblings and occupation of the mother even though have positive coefficients (0.087 and 0.220) respectively, their contribution to the model is not significant (p = 0.69 and p = 0.08 respectively).

DISCUSSION OF RESULS

The study use a random sample of 210 children repeatedly for six months in the study area to find out whether the monthly weight of children recorded at the weighing centers in the metropolis are significantly different and if age and gender could contribute to the weight changes. The descriptive statistics of the mean monthly weight among the three age groups showed that, the children within the ages of 0-6 months (exclusive breast feeding group) had an average weight of 4.738and those of the age group 7-12 had the mean weight of 6.297.Those within the ages 13-18 records an average growth of 7.441. The least significant differences of the means at 5% level for time, age and time × age interaction were 0.0847, 0.3241, and 0.3503 respectively showing that the corresponding differences in mean were significant for age. This suggests that growth of children is thus influence by age with the elderly growing at much faster than the newly born once. The standard errors of the differences of means for time, age and time × age interaction were recorded as 0.0431, 0.1644 and 0.1780 respectively with the interaction having the highest deviation. Closely related to the analysis of the average weight gain to the age was the feeding type. This was so because the type of food taking by infants at the early ages is determine by their ages.

The result also shows that the average weight gain of the children by sex was almost equal with the female gaining an average weight of 6.182 slightly above their male counterpart of 6.136. The error deviation of the time was 0.0464 and that of the gender stood at 0.2038 with the time × gender interaction at 0.2124.

Table 4.2 shows the analysis of variance table for the independent variable by Age of the children. The results reject the null hypothesis that the average weight gain is the same for the three age groups with for the between subject (Age groups) equal to 136.26. This followed the calculation:

$$F = \frac{SSBS/df}{SSE/df} = \frac{1546.4401/2}{1174.6069/207} = 136.26$$

The p- value for the outcome is < .001 which is significant at 5% level. The hypothesis of Age by Time interaction is also rejected with the p-value of < .001 concluding that the effect of both time and age on weight gain is significant.

In tables 4.3 and 4.4, the results explain a similar analysis for feeding type ANOVA and feeding practices with the null hypothesis been rejected in both cases.

In table 4.5, the between subject (gender) effect was not significant. The F ratio for the gender was equal to 0.05 with the F probability of 0.825 far greater than 5% level of significance. Therefore we fail to reject the null hypotheses that gender influence growth in children at the infant stage. The sex of the child is insignificant as far as growth is concerned. Time was significant but the interaction between time and gender was not significant.

The ante dependence analysis for the three age groups and that of the three feeding types, the effect appeared at the first month, the fifth and the seventh months. The ante dependence test for the feeding practice also observed a treatment effect at first month, the third month, the fourth month and that of the sixth month. There was no effect in the second and the fifth months. Table 4.8 present the distribution. Gender did not show any significant effect in all the time point for the six months.

The analysis of variance from the MANOVA approach was used to determine the significance of the effects as suggested above. The time effect was significant but the TIME * GENDER interactions were not significant.

Conclusion

The study was design to determine the significance of Time effect on the weight gain of children less than five years in the Tamale metropolis. The study found negative effects of time × age interaction on the children within 0-6 months in the first month up to the third month and in the last two months with 7-12 months. The effect was positive in the first two month with the age group 13-18.

The results reject the null hypothesis that the average weight gain is the same for the three age groups. The hypothesis of Age by Time interaction was also rejected concluding that the effect of both time and age on weight gain was significant.

The between subject (gender) effect was not significant which means that the sex of the child is insignificant as far as growth is concerned. Time was significant but the interaction between time and gender was not significant.

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