Application of log-linear models to pneumonia patients: a case study of Jigme Dorji Wangchuck National Referral Hospital (JDWNRH) in Bhutan

Sonam Zam and Montip Tiensuwan
Department of Mathematics, Faculty of Science, Mahidol University, Bangkok 10400, Thailand
Email: moon7su@gmail.com

Abstract: Pneumonia is a lung infection or swelling (inflammation) of the tissue in one or both lungs caused by bacteria *Streptococcus pneumonia*. Pneumonia claims the lives of the world’s most vulnerable children. The aim of this study is to find the association between pneumonia variables of pneumonia patients. The recorded data of 4190 JDWNRH pneumonia patients from 2005 to 2016 were used. A test of independence was conducted for all pneumonia patients and individual gender to identify the association between any two variables using chi-square test and Cramer’s V statistic. The variables with maximum Cramer’s V were formulated using two-dimensional log-linear models to obtain estimate parameters, expected frequencies and standardized residuals. Three-dimensional log-linear models were applied to test the association among any three variables. The analysis of deviance is used to select the best models. The result showed that most paired variables were significantly related at p-value less than 0.01. For all data, ward has a strong association with pneumonia types, age, status of last contact and region. In addition, length of stay has association with status of last contact.

1. Introduction

Google defines ‘pneumonia’ as a lung infection or swelling (inflammation) of the tissue in one or both lungs [1]. The bacteria *Streptococcus pneumonia* is one of the most common causes of pneumonia throughout the world. This bacterium was discovered by a French microbiologist Louis Pasteur and an American microbiologist George Sternberg in 1881 [2]. The second major cause of pneumonia is the bacteria known as *Haemophilus influenza*, discovered by Pfeiffer in 1892 [3]. The symptoms of pneumonia are cough, fever, sweating, shivering, loss of appetite, headache, nausea, joint and muscle pain and a hard time breathing. For most people, pneumonia can be treated at home. It often disappears in 2 to 3 weeks yet older people, babies, and people with other diseases can become very ill. They may need to be in the hospital. Some of the effective preventive measures are exclusive breastfeeding for the first 6 months of life, an effective and inexpensive way to treat childhood pneumonia is through the use of antibiotics and vaccines, and using clean cooking stove.

Therefore, the purpose of this study is to identify the associated factors among personal and clinical variables of pneumonia patients using log-linear models.
2. Methodology

2.1 Data collection
In this study, recorded data of 4190 (2323 males and 1867 females) of pneumonia patients from 2005 to 2016 were collected from Jigme Dorji Wangchuck National Referral Hospital (JDWNRH), Bhutan. JDWNRH is renowned across Bhutan for giving the most essential health management and assessment services. Not only the hospital looks into the referred cases by 20 provinces’ hospital, but also keenly serve non-referred cases from the neighboring cities and states with the best of its efforts. The data consisted of personal variables and clinical variables which are shown in Table 1. The personal data includes three variables: age, region and gender. The clinical data includes five variables: pneumonia type, ward, number of visits, length of stay and status of last contact.

| Category          | Divisions                                                                 |
|-------------------|---------------------------------------------------------------------------|
| Personal          |                                                                          |
| Age (years)       | ≤10, 11-20, >20                                                           |
| Gender            | Male, Female                                                              |
| Region            | 1. Southern, Eastern, Western, Central, Others                            |
|                   | 2. Southern, Eastern, Western, Others (only for three-dimensional log-linear models of male and female) |
| Clinical          |                                                                          |
| Pneumonia type    | Pneumonia-unspecified organism, Others                                    |
| Ward              | 1. Pediatric, Medical, Others                                            |
|                   | 2. Pediatric, Others (only for three-dimensional log-linear models of male and female) |
| Hospital visits (days) | ≤ 2, > 2                                                                |
| Length of stay (days) | ≤ 15, 16-30, >30                                                        |
| Status of last contact | 1. Recovered, Death, Others                                           |
|                   | 2. Recovered, Others (only for three-dimensional log-linear models of male and female) |

Some of the categories have more than one divisions, it is to reduce the value being blank or zero.

From Table 2, the personal data show that more than 50 percent of the patients were male and about 54 percent of the pneumonia patients were children aged 10 and below.

From clinical data, most of the patients were diagnosed with pneumonia-unspecified organism. Among wards, most of the patients were admitted in pediatric ward and least patients were admitted in eye and physical ward. About 98.7 percent of the patients visited hospital less than or equals to two days with majority of the patients being admitted in the hospital for less than or equals to 15 days. Status of last contact tells us that with less number of deaths, around 96.1 percent of the patients recovered from pneumonia.

2.2 Statistical Analysis
In this study, we carried out statistical analysis in three stages. A test of independence was conducted to learn about the association between personal and clinical variables, and among personal and clinical variables incorporated with Cramer’s V statistic. Cramer’s V measures the strengths of association between two categorical variables after chi-square has determined significance. The value ranges from 0
to 1. A value close to 0 indicates a weak association between variables and close to +1 shows a strong
association. The Cramer’s V can be obtained by

$$V = \sqrt{\frac{\chi^2}{n(v-1)}},$$

(1)

where $\chi^2$ is derived from chi-squared test, $v$ is the smaller of the number of rows and columns, and $n$
is a sample size. This statistic, Cramer’s V can attain the maximum of 1 for tables of any dimension.

| Table 2: Descriptive data for personal data and clinical data classified by gender |
|-------------------|-----------------|----------------|-----------------|
| Variables         | Male            | Female         | Total           |
|                   | Number | %     | Number  | %     | Number | %     |
| **Personal data** |                  |                 |                 |
| Age (years)       |                  |                 |                 |
| ≤ 10              | 1274   | 54.8  | 972     | 52.1  | 2246   | 53.6  |
| 11-20             | 576    | 24.8  | 511     | 27.4  | 1087   | 25.9  |
| > 20              | 473    | 20.4  | 384     | 20.6  | 857    | 20.5  |
| Region            |                  |                 |                 |
| Southern          | 891    | 38.4  | 709     | 38.0  | 1600   | 38.2  |
| Eastern           | 451    | 19.4  | 338     | 18.1  | 789    | 18.8  |
| Western           | 486    | 20.9  | 464     | 24.9  | 950    | 22.7  |
| Central           | 456    | 19.6  | 344     | 18.4  | 800    | 19.1  |
| Others*           | 39     | 1.7   | 12      | 0.6   | 51     | 1.2   |
| **Clinical data** |                  |                 |                 |
| Pneumonia type    |                  |                 |                 |
| Pneumonia,        | 2143   | 92.3  | 1716    | 91.9  | 3859   | 92.1  |
| Unspecified organism | 180   | 7.7   | 151     | 8.1   | 331    | 7.9   |
| Others**          |                  |                 |                 |
| Ward              |                  |                 |                 |
| Pediatric         | 1796   | 77.3  | 1408    | 75.4  | 3204   | 76.5  |
| Medical           | 187    | 8.0   | 153     | 8.2   | 340    | 8.1   |
| Others***         | 340    | 14.6  | 306     | 16.4  | 646    | 15.4  |
| Hospital visits   |                  |                 |                 |
| ≤ 2               | 2293   | 98.7  | 1842    | 98.7  | 4135   | 98.7  |
| > 2               | 30     | 1.3   | 25      | 1.3   | 55     | 1.3   |
| Length of stay (days) |         |                 |                 |
| ≤ 15              | 2220   | 95.6  | 1787    | 95.7  | 4007   | 95.6  |
| 16-30             | 82     | 3.5   | 68      | 3.6   | 150    | 3.6   |
| > 30              | 21     | 0.9   | 12      | 0.6   | 33     | 0.8   |
| Status of last contact |        |                 |                 |
| Recovered         | 2232   | 96.1  | 1797    | 96.3  | 4029   | 96.2  |
| Death             | 86     | 3.7   | 66      | 3.5   | 152    | 3.6   |
| Others****        | 5      | 0.2   | 4       | 0.2   | 9      | 0.2   |

*Note: *such as India, China, Australia & Bangladesh. **such as pneumonia due to influenza virus, Streptococcus pneumonia, etc. ***such as neonatal, eye, etc. ****such as absconded & referred out.

### 2.2.1 Two-dimensional log-linear models

The model given is applied to study the association between any two variables. The saturated or maximal model is written as
\[
\text{LogE}(Y_{jk}) = \mu + \alpha_j + \beta_k + (\alpha\beta)_{jk},
\]
where \(\mu\) is the grand average of the logarithms of the expected frequencies, \(\alpha_j, \beta_k\) are the main effects of the factors, and \((\alpha\beta)_{jk}\) is the interaction effect of two factors with degrees of freedom 

\[
1 + (J - 1)(K - 1) + (J - 1)(K - 1)(L - 1) = JK.
\]

### 2.2.2 Three-dimensional log-linear models

Like Two-dimensional models, three-dimensional models are applied to study the association between any three variables. The full model is given by

\[
\text{LogE}(Y_{jk}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha\beta)_{jk} + (\alpha\gamma)_{jl} + (\beta\gamma)_{kl} + (\alpha\beta\gamma)_{jkl}.
\]

where \(\mu\) is the grand average or overall mean, \(\alpha_j, \beta_k, \gamma_l\) are the main effects of the factors, \((\alpha\beta)_{jk}\), \((\alpha\gamma)_{jl}\), \((\beta\gamma)_{kl}\), and \((\alpha\beta\gamma)_{jkl}\) are the interaction effects of two factors, and \((\alpha\beta\gamma)_{jkl}\) is the interaction effects of three factors, with 

\[
1 + (J - 1) + (K - 1) + (L - 1) + (J - 1)(K - 1) + (J - 1)(L - 1) + (J - 1)(K - 1)(L - 1) = JKL.
\]

### 2.2.3 Goodness of fit

Goodness of fit test is used to determine whether a log-linear model used matches the real scenarios.

- \(H_0\): The smaller model fits the data well.
- \(H_1\): The larger model fits the data well.

Chi-squared statistic and log-likelihood ratio statistic are used to measure goodness of fit for contingency tables as followings:

1. Chi-square statistic is

\[
\chi^2 = \sum \sum (O_{jk} - E_{jk})^2 / E_{jk}.
\]

The test is to reject \(H_0\) if \(\chi^2 > \chi^2_{\alpha,(J-1)(K-1)}\) and accept \(H_0\) otherwise, with an approximated significance level \(\alpha\), and degrees of freedom \((J - 1)(K - 1)\).

2. The log-likelihood ratio statistic or deviance is

\[
G^2 = 2 \sum \sum O_{jk} \log \frac{O_{jk}}{E_{jk}}
\]

with \((J - 1)(K - 1)\) degrees of freedom. Thus, the test is to reject \(H_0\) if \(D > \chi^2_{\alpha,(J-1)(K-1)}\) and accept \(H_0\) otherwise.

### 3. Results and discussion

In this section, we present the results from testing associations between two distinct pneumonia variables for male and female patients using chi-square statistic and Cramer’s V. Table 3 illustrates the summary of the relationship between the personal and clinical variables which gave maximum Cramer’s V for male and female pneumonia patients at \(p\)-value < 0.01.

Table 3 shows that ward and status of last contact, length of stay and status of last contact, age and ward, and region and ward have strong association for both the genders. However, pneumonia type and ward had association only for male patients. It also indicates that ward is having a strong relationship with personal variables as well as clinical variables.
Table 3: Summary of the association between variables in personal data and clinical data which produced maximum Cramer’s V value

| Variable                                      | Chi-square | d.f. | p-value | Cramer’s V |
|-----------------------------------------------|------------|------|---------|------------|
| Male                                          |            |      |         |            |
| Pneumonia type and ward                       | 14.920**   | 2    | 0.001   | 0.080^     |
| Ward and status of last contact               | 142.520**  | 4    | <0.001  | 0.175^     |
| Length of stay and status of last contact     | 19.586**   | 4    | 0.001   | 0.065^     |
| Age and ward                                  | 955.964**  | 4    | <0.001  | 0.454^     |
| Region and ward                               | 266.466**  | 8    | <0.001  | 0.239^     |
| Female                                        |            |      |         |            |
| Ward and status of last contact               | 60.995**   | 4    | <0.001  | 0.128^     |
| Length of stay and status of last contact     | 34.662**   | 4    | <0.001  | 0.096^     |
| Age and ward                                  | 729.264**  | 4    | <0.001  | 0.442^     |
| Region and ward                               | 184.321**  | 8    | <0.001  | 0.222^     |

**Note:** ** significant at p-value <0.01, ^ maximum Cramer’s V value for each variable.

Two-dimensional log-linear models

From Table 3, we choose the two variables which had an association and gave the maximum Cramer’s V-value to formulate the two-dimensional log-linear models, and acquired 9 models: 5 for male and 4 for female, in the form \( \log[\mathbb{E}(Y_{jk})] = \mu + \alpha_j + \beta_k + (\alpha\beta)_{jk} \). We present only one model corresponding to that of age and ward for male patients in Table 4.

Table 4: The frequencies (percent) of age and ward for male patients

| Ward   | Age  | Total |       |       |       |       |       |       |       |
|--------|------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | <=10 | 11-20 | >20   |       |       |       |       |       |       |
| Pediatric | 1161(49.98) | 494(21.27) | 141(6.07) | 1796(77.31) |
| Medical  | 0(0.00)   | 9(0.39)  | 178(7.66) | 187(8.05)  |
| Others* | 113(4.86) | 73(3.14) | 154(6.63) | 340(14.64) |
| Total   | 1274(54.84) | 576(24.80) | 473(20.36) | 2323(100.00) |

**Note:** * such as neonatal, eye, etc.

In addition, we have also fitted the model under \( H_0 \) and the maximal model under \( H_1 \) and obtained \( \chi^2 = 955.964 \), the log-likelihood ratio statistic (D) = 847.053 and degrees of freedom (d.f.) = 4, hence at a significance level 0.05 we reject \( H_0 \) and select the maximal or saturated model. The estimates of the main effects of interaction terms of the saturated model are given in Table 5.

Table 5: Estimates of parameters of saturated model for age and ward for male patients

| Parameter | Model under \( H_0 \) | Saturated model | Parameter | Model under \( H_0 \) | Saturated model |
|-----------|------------------------|----------------|-----------|------------------------|----------------|
| \( \mu \) | 7.057                  | 6.893          | \( \alpha_1 \) | 0.000                  | 0.000 |
| \( \alpha_2 \) | -33.004               | -2.262         | \( \alpha_3 \) | -2.330                 | -1.664 |
| \( \beta_1 \) | 0.000                  | 0.000          | \( \beta_2 \) | -0.855                 | -0.794 |
The other models were obtained in the same way. The log-likelihood ratio statistic, chi-square value and degrees of freedom for the associated variables for individual gender are represented in Table 6.

**Table 6**: The log-likelihood ratio statistic, chi-square value and degrees of freedom for associated variables on male and female patients

| Associated variables | D   | $\chi^2$ | d.f. | p-value |
|----------------------|-----|----------|------|---------|
| **Male**             |     |          |      |         |
| Ward and pneumonia type | 12.260 | 14.920 | 2    | 0.001   |
| Ward and status of last contact | 112.415 | 142.520 | 4    | <0.001  |
| Ward and age         | 847.053 | 955.964 | 4    | <0.001  |
| Region and ward      | 254.654 | 266.466 | 8    | <0.001  |
| **Female**           |     |          |      |         |
| Ward and status of last contact | 50.316 | 60.995 | 4    | <0.001  |
| Length of stay and status of last contact | 15.478 | 34.662 | 4    | <0.001  |
| Ward and age         | 656.510 | 729.264 | 4    | <0.001  |
| Region and ward      | 185.508 | 184.321 | 8    | <0.001  |

**Three-dimensional log-linear models**

In this section, we determine whether or not any association is the same for both the gender for all patients and for individual gender. Farr et al. [4], found that crude death rates from pneumonia for male is more than for female, that is why gender has been selected as one in each set of three variables for all patients. We selected age as one in each set of three variables for individual gender because pneumonia is the infectious cause of death in children under the age of 5 [5]. The other two variables for each set are age and region, pneumonia type and ward, ward and status of last contact, length of stay and status of last contact, age and ward, and region and ward for all patients and pneumonia type and ward, ward and status of last contact, length of stay and status of last contact, age and ward, region and ward for male patients, and ward and status of last contact, length of stay and status of last contact, age and ward, and region and ward for female patients. From these, three-dimensional log-linear models were formulated using the values of deviance difference and deviance difference degrees of freedom to obtain the best models. The results are shown in Table 7, however we present only one model in detail that is for the ward, status of last contact and age for female patients but other models are also obtained in the same manner.

**Table 7**: Analysis of deviance for the ward, status of last contact and age for female patients

| Model | Parameter | Deviance | d.f. | Deviance difference | d.f. difference |
|-------|-----------|----------|------|---------------------|-----------------|
| (1)   | Full model: $\mu, \alpha_j, \beta_i, \gamma_l$, $(\alpha\beta)_j, (\alpha\gamma)_j, (\beta\gamma)_j$ | 0 | 0 | - | - |
| (2)   | Delete $(\alpha\gamma)_j$ from (1) | 16.649 | 2 | 16.649* | 2 |
| (3)   | Delete $(\alpha\beta)_j$ from (2) | 28.507 | 3 | 11.858* | 1 |
| (4)   | Delete $(\alpha\gamma)_j$ from (2) | 544.854 | 5 | 528.199* | 5 |
| (5)   | Delete $(\beta\gamma)_j$ from (2) | 618.532 | 7 | 601.883* | 5 |

**Note**: * significant at p-value < 0.01

According to the chi-square, the best model is (2), that is $\log[E(Y_{ij})] = \mu + \alpha_j + \beta_i + \gamma_l + (\alpha\beta)_j + (\alpha\gamma)_j + (\beta\gamma)_j$, $j = 1, 2; k = 1, 2; l = 1, 2$, which shows that, for female patients, age is related with ward and
status of last contact, while ward is related to status of last contact. The observed frequency, expected frequency and standardized residual of ward, status of last contact and age are shown in Table 8.

Table 8: Observed, expected frequency and standardized residual of ward, status of last contact and age for female patients

| Cell | Observed (Expected under $H_1$) | Expected under $H_0$ | Standardized Residual |
|------|--------------------------------|----------------------|-----------------------|
| 1    | 853                           | 854.5144             | -0.0518               |
| 1    | 1                             | 23.4856              | 0.3125                |
| 2    | 93                            | 91.4856              | 0.1583                |
| 2    | 1                             | 2.5144               | -0.9550               |
| 1    | 418                           | 417.1820             | 0.0400                |
| 1    | 2                             | 0.8180               | -0.9044               |
| 2    | 92                            | 92.8180              | -0.0849               |
| 2    | 1                             | 0.1820               | 1.9175                |
| 1    | 111                           | 99.4583              | 1.1573                |
| 1    | 1                             | 12.5417              | 112.0000              |
| 2    | 230                           | 241.5417             | -0.7426               |
| 2    | 42                            | 30.4583              | 2.0913                |

The best model of three-dimensional log-linear models for each set of three variables is summarized in Table 9. According to the three-dimensional log-linear models, the best models for each set of three variables are not the same. The relationship among variables in each set contributed for choosing the best model.

From Table 8, there is an interaction of three effects in models (1), (6), (7), (8), (10), (11), (13). Model (1) shows that the association between age and region is not the same for both the gender. Model (2) illustrates that the distribution of gender is same for the ward and pneumonia type. According to the best model, model (3), the association between ward and status of last contact is the same for both genders. As per model (4), the association between length of stay and status of last contact is the same for both genders. Likewise, model (5) depicts association of gender being depended on ward and age. Model (6) shows that the association between ward and region is not the same for both genders. As per model (7), the dispersal of age is not the same for pneumonia type and ward. Model (8) and model (11) demonstrates that the association of ward and status of last contact is not equivalent for all ages. According to the best model, model (9) and model (12), length of stay and status of last contact depended on age. Similarly, models (10) and (13), the association between age and ward is not the same for region.

4. Conclusion

In our study, we have shown only the relative variables which give the maximum Cramer’s V value in each table of association. There are numerous studies in the world that have investigated on pneumonia. A special feature of this study is being the first research to be carried out in studying pneumonia patients using log-linear model in Bhutan and this approach led to a valuable result which can be used by experts in Bhutan to battle against pneumonia.

This study showed that most paired variables were significantly related at p-value less than 0.01. For all patients and individual gender, ward has a strong association with pneumonia types, age, status of last contact and region. In addition, length of stay has association with status of last contact. From the numerical results, we can see that most of the pneumonia patients are residing in southern region of Bhutan while there were less patients from other countries like Australia, Bangladesh, India and China receiving treatment in Bhutan.
Table 9: Summary of the best model of three-dimensional log-linear models

| Variables                                      | The best model                                                                 |
|------------------------------------------------|-----------------------------------------------------------------------------|
| (1) Age \((\alpha_j)\), region \((\beta_k)\), and gender \((\gamma_l)\)      | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl} + (\alpha \beta \gamma)_{jkl}\), |
|                                                 | \(j = 1, 2, 3; k = 1, 2, 3, 4, 5; l = 1, 2)                          |
| (2) Ward \((\alpha_j)\), pneumonia type \((\beta_k)\), and gender \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2, 3; k = 1, 2; l = 1, 2)                                   |
| (3) Ward \((\alpha_j)\), status of last contact \((\beta_k)\), and gender \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2, 3; k = 1, 2, 3; l = 1, 2)                              |
| (4) Length of stay \((\alpha_j)\), status of last contact \((\beta_k)\), and gender \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2, 3; k = 1, 2, 3; l = 1, 2)                              |
| (5) Ward \((\alpha_j)\), age \((\beta_k)\), and gender \((\gamma_l)\)      | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2, 3; l = 1, 2)                               |
| (6) Ward \((\alpha_j)\), region \((\beta_k)\), and gender \((\gamma_l)\)   | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2, 3, 4, 5; l = 1, 2)                         |
| (7) Pneumonia type \((\alpha_j)\), ward \((\beta_k)\), and age \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2; l = 1, 2, 3)                              |
| (8) Ward \((\alpha_j)\), status of last contact \((\beta_k)\), and age \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2; l = 1, 2, 3)                              |
| (9) Length of stay \((\alpha_j)\), status of last contact \((\beta_k)\), and age \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2; l = 1, 2, 3)                              |
| (10) Ward \((\alpha_j)\), region \((\beta_k)\), and age \((\gamma_l)\)    | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2, 3, 4; l = 1, 2, 3)                        |
| (11) Ward \((\alpha_j)\), status of last contact \((\beta_k)\), and age \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2; l = 1, 2, 3)                              |
| (12) Length of stay \((\alpha_j)\), status of last contact \((\beta_k)\), and age \((\gamma_l)\) | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2; l = 1, 2, 3)                              |
| (13) Ward \((\alpha_j)\), region \((\beta_k)\), and age \((\gamma_l)\)    | \(\log E(Y_{ijkl}) = \mu + \alpha_j + \beta_k + \gamma_l + (\alpha \beta)_{jk} + (\alpha \gamma)_{jl} + (\beta \gamma)_{kl}\), |
|                                                 | \(j = 1, 2; k = 1, 2, 3, 4; l = 1, 2, 3)                        |

The prevalence of pneumonia was found to be highest among children and male patients. Since pneumonia is the number one infectious diseases killer of children, pediatric ward had the highest number of patients being admitted with more being male. About 98.7 percent of the patients visited hospital less than or equals to two days with majority of the patients being admitted in the hospital for less than or equal to 15 days. Status of last contact tells us that with less number of deaths, around 96.1 percent of the patients recovered from pneumonia.

Bhutan Multiple Indicator Survey (2010) [6], reveals that about 7% of the children are reported to have had the symptoms of Pneumonia and 74% of children are said to have received treatment at the health care unit. Rest 26% have not received any treatment, though 26% seems small, the battle with pneumonia has
not ended. Nevertheless, with awareness campaign on importance of breast feeding, living in clean surroundings, using antibiotics and vaccines, there are reduction in pneumonia patients with each year.

Though the frequency of hospital visits influences the severity of pneumonia, it could not find an association with any of the personal and clinical variables using log-linear models. The log-linear model only determines the association between the variables [7]. Therefore, another interesting study would be on pneumonia variables using logistic regression models.

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