Risk Factors and Pattern of Asthma Admissions in Scotland (1981-1992)

By

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To the memory of my father and mother, Solayman Eshraghian and Zaman Ghafari

To my dearest ones, my wife Jila Ghafari and my two lovely children, Kaveh and Shekofeh

To my dear brother, Kiomars Eshraghian, and my sisters

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Summary

There has been a number of reports claiming that asthma admissions (and readmissions) have been steadily increasing in recent years. In some of these researches the possible risk factors for asthma admissions have been discussed but in none of them have first and later asthma admissions been considered separately. The aim of this study is to discover the pattern and some of the risk factors for asthma admissions to Scotland's hospitals in years 1981 to 1992. Four aspects differentiate this study from others. First, the linked records of admissions of asthmatic patients are used. Second, the first and later admissions of patients are analysed separately. Third, the data covers all Scotland (which could be assumed to be a closed medical area) for a relatively long period of time (12 years). Fourth, more complex models (i.e. Cox Proportional Hazards model) with the idea of analysing times free of admission are used to model the pattern or identifying the risk factors. Note it is necessary to use the linked records of admissions in a closed medical area to be able to distinguish between first and later admissions of asthmatic patients. The data was provided by the Scottish Record Linkage Study, Scottish Health service, Statistics Division, Edinburgh.

Our decision for identifying whether an admission of an asthmatic patient is his/her first asthma admission or one of his/her later asthma admissions was based on whether the patient has not or has any admission (due to asthma) at least within 3 years before the date of first recorded admission.

To achieve a 3 years support for not having any asthma admission before first recorded asthma admission (for those patients whose first recorded admissions was in year 1984), the admissions data in years 1981, 1982 and 1983 was used. We deleted all admissions corresponding to those asthmatic patients whose first recorded asthma admission occurred in years 1981-1984. It makes it possible to consider the whole pattern of asthma admissions of those asthmatic patients who are included in the study. As the final data set, the file which is the basic file for all analyses, contains 69814 asthma admissions (with either first or second diagnosis as asthma) belonging to 40496 asthmatic patients whose first asthma admission (i.e. first hospitalisation) occurred between year 1984 to 1992. Later, for analysing the pattern of later admissions of the asthmatic patients, it was decided to consider each asthmatic patient's later asthma admissions in a 3 year horizon after the first asthma admission. Some more modifications were carried out on the basic data file to count the number of later asthma admissions of each asthmatic patient in the 3 years after his/her first asthma admission. In analysing the pattern of later asthma admissions, only the effect of explanatory variables at time of first asthma admission on the pattern of later asthma admissions was studied. We also showed that on average 95% of first admissions are correctly recognised from first recorded admissions in the present data. The available data, the modifications which were done on the initial data set and the precision of the choice of a minimum 3 years support for identifying the first asthma admission from the first recorded admission are fully described in sections 1-2, 2-1 and 2-2.

We defined four types of first admission according to whether asthma is first/second reason of hospitalisation or admission to hospital is non-emergency/emergency.

In chapter 2 we showed that there is a strong seasonal pattern for asthma admissions which has repeated itself through years 1984 to 1992 (see plot 2-4-1). Over these years, the number of first asthma admissions has increased sometimes sharply (see plot 2-5-1). Usually such sharp increases (in first admissions) are related to some changes in policies, for example hospitalisation policy, rather than to a real change in severity or incidence of the disease. The important increase in first asthma admissions has occurred during years 1989 to 1991, two jumps, one in 1990 and another one in 1991.

In 2-5 we considered the number of later admissions in a 3 years horizon in each cohort of first admissions in each age group (see plot 2-5-4) and showed that there was little change in the number of later admissions per patient (except for babies). Comparing this result with another plot (see plot 2-5-2) may lead us to this very important result that recent increase in number of asthma admissions in Scotland corresponds to an increase in first admissions (i.e. new asthmatic patients) (and only in age groups 0-2 and more than 15 years) and not to previously known or treated patients.

In 2-7 we discussed also the pattern of intensity of later asthma admissions and discovered that in overall, in different age groups, the mean intensity of returning to hospital decreases as the year since the first admission increases and the pattern of decrease is similar for all age groups. Initial intensity is greatest for babies, but after 5 years all age groups have mean intensity about 0.1 per year. After 5 years a baby is no longer a baby. The year of first asthma admission has not any effect, or maybe a very small effect, on intensity of later asthma admissions.

In chapter 3 we fitted loglinear models, one for each of the four types, to investigate the relation between numbers of first admissions and different factors. The main effects and the same 2-factor interactions were fitted to a

grouped contingency table. Validation was on the whole successful. Plots of estimated expectations of counts illustrated different age patterns in different cities (for all years and both sexes), different trends in cities and age-groups (for both sexes); and the different sex ratios for adults and children/babies (in all cities and years).

In chapter 4, Weighted Regression was used to investigate the relation between later asthma admissions, in a 3 year horizon after first admission, and a number of factors. The Logistic model also was used to model, at certain point, the probability function of returning to hospital. Fitted models to the mean of later admissions of patients whose first admissions were the most common type (i.e. first diagnosed, emergency admissions, called as type 2) indicated that babies return to hospital more frequently than children and adults, and adults return more frequently than children. Among babies, the age group is the only factor which is related to mean of later asthma admissions i.e. mean of later asthma admissions of babies is not even related to factor "sex". For two other age groups (children and adults), the effect of age group is different for male and female. "Year of first admission" is also relevant. Girls and women return to hospital more frequently than males.

Probability tables of having 0 (i.e. not returning to hospital), more than 2 and more than 3 later admissions, are shown in chapter 4 as well. These tables confirm the importance of age and sex. The probability of "Not returning to hospital" for patients with first admission of types 1, 2, 3 and 4 are respectively, 0.73, 0.67, 0.85 and 0.77.

In section 4-6 we fitted separate logistic models to $P(X>0)$, $P(X>2|X>0)$ and $P(X>3|X>2)$. Then we used the cumulative conditional logistic regression and fitted a single model to all these 3 probabilities. In 4-6-4 we compared the results from these two approaches.

In chapter 5 the Cox Proportional Hazard model was used to model first, second and third times free of admission using age, sex, year, city as well as length of most recent stay in hospital. When the second and third times free of admissions were being modelled, we used previous time(s) as well as previous length(s) of stay in hospital as new covariate(s). The effect of factor age was consistent with the effect which was reported in previous chapters. We discovered that patients who have shorter previous time(s) free of admission are more likely to return to hospital i.e. they have a shorter next time free of admission as well. The effect of recent length of stay or previous length of stay was opposite to the effect of previous(s) time(s) free of admission i.e. those patients who have shorter recent length of stay or shorter previous length of stay in hospital are less likely to return to hospital. The patient who is more seriously ill returns sooner.

In chapter 6 we investigated the distribution of complete times free of admission for some individual patients (having at least 15 admissions). In this chapter we also showed that a patient's time free of admission was related at most to his/her two recent previous times.

In chapter 7 we have considered possibilities for further analyses, including use of Multilevel Models. In this chapter we have also discussed some methodological issues and some problems.

Conclusions are discussed in chapter 8.

Chapter 1

1-1: Introduction :

Asthma is a common illness in the United Kingdom. Asthma admissions have been rising steadily in the UK. for many years and it is estimated that the prevalence, severity and mortality of asthma have increased in recent years in all age groups (Cedrick R. 1992, Warner J. 1989, Fleming D.M. 1987). There has been speculation about whether the rise in the number of asthma admissions represents a true increase in the number of patients who were treated by the National Health Service or whether it may simply reflect an increase in repeat admissions (Goldacre M.J. 1988).

During the past 20 years there has been a regular output of studies concerned with pattern of asthma admission to hospitals. Many of these studies considered asthma admissions, asthma readmissions or multiple admissions due to asthmatic patients (Williams I.E. 1988). In some of these studies, attempts have been made to identify the factors which might lead to asthma admissions as well as to having multiple admissions. It has been tried to relate the asthma admissions, as well as the asthma readmissions, to factors such as age of patient (Baribean-braun J. 1979), sex of patient (Williams I.E. 1988), type of discharge (Munley P.H. 1977), contact with family (Baribean-braun J. 1979), occupational state (Bunside I.C. 1983), patient' s compliance (Hood J.C. 1978), patient in a home for elderly people (Hodkinson H.M. 1980), chronic disability

(Hodkinson H.M. 1980), unavoidable relapse (Graham H. 1983, Kendrick S. 1992), inadequate medical management and poor rehabilitation (Graham H. 1983). In some of the above studies it has been tried to use the readmission rate as a measure of quality of care or quality of managing a specific disease in hospitals.

In all studies about pattern of asthma readmission or pattern of asthma multiple admissions in any area, it is necessary to use linked data in the area, otherwise the calculated rates are underestimated.(Goldacre M.J. 1988, Kendrick S. 1992) The reason for need for linked data is to make sure we have not lost some admissions of an asthmatic patient in other hospitals or other cities. If any admission of an asthmatic patient is lost then the pattern which we are looking at, is not the actual pattern. Note in this case the calculated readmission rate or multiple admission rate are underestimated because some admissions are lost.

The availability of linked data means that one patient's admissions can be followed up in different hospitals in a relatively wide area. The area could be the city in which hospitals are included or could be the country or even a set of countries. The first linked data which was used in many studies belonged to Oxford district (Goldacre M.J. 1988, Baldwin J.A. 1987, Heasman M.A. 1968, Henderson J. 1989). In this data, all admissions of a patient, to any hospital in Oxford district are linked.

In recent years linked data of Scotland's hospitals has also been produced by Scottish Health Service. In this data set all admissions of any particular patient have been linked together throughout Scotland. As far as we know, considering the extent of the area, this data set is unique in the whole world.

In this study it is intended to use the above mentioned linked data set (Scottish Record Linkage) to identify the risk factors for and the pattern of admission for asthmatic patients in Scotland. There are three important aspects which in combination, make this research unique. These are, first, the use of linked data, second, the size of data set which is going to be used (nearly 250,000 asthma admissions) and finally, distinguishing between first and later admissions that later we will discuss.

1-2: The Data Available:

As was explained in the introduction, the data set which is available for studying the pattern of asthma admission in Scotland is a very large data set of linked admissions which is prepared by the Scottish Health Service. The Scottish Health Service has provided the Scottish Record Linkage System (Kendrick S. 1992) and at present time the linked data of patients' admissions and some covariates related to their admissions are stored as conventional flat file of records with the records for each individual stored adjacently in chronological order and marked with a unique personal identifier (Kendrick S. 1992, Heasman M.A. 1979).

Development of linked data in Scotland began in May 1989 as a joint project between the "Information and Statistics Division" and the "Common Services Agency Data Centre" of the Scottish Health Services (Kendrick S. 1992). The morbidity data set holds 12 years (1981-1992) of hospital admission records for non-psychiatric, non-obstetric specialities (SMR1) together with Scottish Cancer Registry records (SMR6) and Registrar General's death records, around nine million records in total (Kendrick S. 1992). As far as we know, this linked data set is unique in the whole world because in no other country has the hospitals' admissions of a particular patient been linked in such a large area. As it is unlikely that any admission of patients are lost due to being admitted to other hospitals not in Scotland, this data set can be used to study the pattern of readmissions or multiple admissions without being worried about underestimation of respective rates.

The different types of records are stored in their original unlinked format preceded by several fields of linkage information. Storing the data in its original form means that any information contained in the unlinked records is available for the analysis. The main advantage is flexibility in terms of the range of analyses. The main feature is relatively complex to work with requiring the use of bespoke FORTRAN programs to access the data. Each record in the data has all fields on the "Inpatient and Day Case Record Summary Sheet" form i.e. fields like age, sex, postcode, general practitioner code, hospital code, type of admission, date of joining waiting list, category of patient, consultant code, date of admission, date of discharge, date of death (if death has occurred in hospital), speciality code and main diagnoses, all are identified for each patient in each admission. Note that these are the possible covariates which can be used in modelling the pattern of asthma admissions. It is claimed that there is only five percent error in linking the data (Kendrick S. 1992).

It is clear that to study the pattern of asthma admissions to hospitals, we need to choose only those admissions from the above mentioned data set which are related to asthma. The data set which was derived from the original linked data set, contained 249,559 records of admissions. These are all admissions, whether or not related to asthma, belonging to all patients who had been hospitalised, at least once, in one of the Scotland's hospitals with asthma diagnosis, either as first or second diagnosis, between years 1981 to 1992. All covariates which existed in the source file and were mentioned in the previous paragraph, were transferred to new data file. The asthmatic patient is defined as a patient whose diagnosis code was established as "493" in his/her record. According to the World Health Organisation's classification (Intentional Classification of Diseases , Ninth Revision, ICD9), the code "493" is used for

asthma disease. As we noticed the data set contained a 4 digit code for diagnosis. For asthma these were "4930", "4931" or "4939", belonging to different types of asthma. We did not discover any change of codes during the study period (i.e. between years 1981 to 1992). In addition to existing covariates for each asthmatic patient, some new variables were created that we will mention in later sections. Note that the file which is chosen for the analysis, contains some admissions which are not related to asthma (but belong to asthmatic patients). Some modifications were carried out to prepare this file for analyses. We will mention these modifications later in section 2-1.

1-3: Asthma :

* This section consists of direct quotation from references Clark T.J.H. 1977, Colins J.V. 1975, Costello J.F. 1974 and Crofton J. 1974.

1-3-1: Definition :

A condition in which there is variable breathlessness due to widespread narrowing of intrapulmonary airways which varies in severity over short period of time, either spontaneously or with treatment.

1-3-2: Aetiology and Pathogenesis:

Variable narrowing of the peripheral airways (bronchoconstriction) is due to one or all of the following : (1) contraction of bronchial smooth muscle; (2) oedema of the mucous membrane; and (3) mucus within the lumen.

Bronchoconstriction is a normal response to noxious stimuli such as cigarette smoke and sulphur dioxide - also to alterations in the concentration of oxygen and carbon dioxide in the lumen. These responses are either direct or mediated reflexly by the vagus nerve. Normal bronchial 'tone' can be demonstrated in bronchial musculature by decrease in airways resistance after administration of atropine or isoprenaline. All these physiological responses are very small in degree and are not felt by a normal individual.

Various agents such as histamine, bradykinin, slow-reacting substance in anaphylaxis (SRS-A), prostaglandins, and 5-hydroxytryptamine are liberated. There are also other as yet unidentified substances which are released in the bronchial wall probably from mast cells too. All of these agents, both known and unknown, cause bronchoconstriction and their relative importance is

uncertain. Many factors appear to be responsible either directly or indirectly for release of these mediators amongst which are exercise, allergy, infection, but the actual mode of release is conjectural. Other factors, for instance psychological or pharmacological, may potentiate bronchoconstriction.

Exercise : This frequently brings about bronchoconstriction in asthma and this may be detected by simple tests of ventilation in patients many years after a complete clinical remission.

Allergy : In acute asthma bronchoconstriction is usually the end result of an immediate hypersensitivity response to one or more allergens to which the patient has become sensitised. Persistence of bronchoconstriction must be due to other, perhaps secondary, mechanisms whether hypersensitivity or otherwise (e.g. liberation of lysozymal enzymes, kinns, or prostaglandins). Entry of the allergen is usually by inhalation but rarely, as for instance in the case of milk, aspirin, and Toxocara canis, by ingestion.

Asthma is broadly divisible into two groups: **extrinsic** in which there is an external factor which can be detected or inferred and **intrinsic** (non-extrinsic). Extrinsic asthma is much more common. These two forms of asthma differ characteristically as follows :

Extrinsic	Intrinsic
IgE raised in at least 70 per cent	IgE normal or low
Usually atopic subjects.	Non-atopic subjects.
Onset in early years.	Onset in middle age.
Often intermittent.	Usually constant.
Family history of atopy.	Family history of asthma.

Infection : Bacterial or viral infection may be an important factor at the onset and in the course of asthma. The mechanism by which the infection may provoke or prolong asthma remains unknown though allergy to bacterial protein as well as the direct effect of inflammatory reactions in the bronchial mucosa are possible. Circulating precipitating antibody to bacteria may be found in 17 per cent of infected asthmatics, and in only 3 per cent of non-infected asthmatics, though the role of these antibodies is uncertain. Infection in asthma adversely affects the prognosis.

Psychological factors : Families of asthmatics have a higher than normal incidence of neurosis and psychiatric illness, as do the asthmatics themselves. In about 40 per cent of asthmatics psychological factors are present but their mode of action is unknown. Almost certainly they merely intensify the asthma rather than exert any causal influence.

Pharmacological factors : β-Adrenergic blockade causes bronchoconstriction in asthma but not in normal subjects. This implies that there is enhanced adrenergic activity in asthma. Drugs such as propranolol should be avoided.

Chronic chest disease as well as asthma, hay fever, and eczema are more common in families which contain asthmatics. The incidence of asthma in first-degree relatives approaches 40 per cent after the age 65. The mode of inheritance is unknown.

The incidence of bronchial asthma in general population is in the order of 1-2 per cent and it affects social classes equally. No race is exempt. In Birmingham in 1961 asthma was observed to be twice as common in boys (2.58

per cent) at 5 years of age as in girls (1.02 per cent) of the same age. The prevalence in boys fell with age so that the sex difference was abolished by early adult life.

1-3-3: Physiological Changes:

Variable narrowing of intrapulmonary airways is the characteristic physiological change in asthma. This airways obstruction usually gives rise to an increase in airways resistance which may be diminished by bronchodilator drugs. These drugs may be adrenergic (e.g. isoprenaline, adrenalin, salbutamol), anticholinergic (e.g. atropine), and others (e.g. aminophylline).

1-3-4: Clinical Picture:

The dominant symptom in bronchial asthma is breathlessness -an unpleasant awareness of difficulty in breathing which may which may be sensed not only in expiration but in inspiration especially when there is marked hyper-inflation. Tightness in the chest is then also a component of the dyspnoea. Wheezing usually accompanies both inspiration and expiration unless the asthma is so severe that the reduced air flow is unable to create the sound. The pattern of wheezy breathing varies considerably. It may be episodic in which the episodes are short or long or it may persist for very long periods.

In extrinsic asthma the attacks are usually episodic with periods of complete freedom between times. This form of asthma usually starts in childhood. Characteristically there is an allergic background of infantile eczema or hay fever. The wheezing may be seasonal at first. Attacks vary in frequency and duration. Wheezing is often provoked by exercise and is usually

worse during the night. Attacks may be precipitated by inhaled allergens such as pollens or dust of animal danders or hair. Asthma may occur at times of emotional stress or with acute respiratory infection. Sometimes no precipitating factors can be found on questioning but psychological factors may be observed. With intrinsic asthma on the other hand wheezy breathlessness although episodic at first tends to be much more persistent. The illness usually starts later in life, often in the late 20s or 30s, but no age is exempt. A frank allergic background is not found but perennial rhinitis is not common. Aspirin sensitivity is sometimes a feature and nasal polyps not an infrequent finding. The onset of intrinsic asthma is often related to an acute respiratory infection and persistence of infection is a serious matter.

Asthma may be associated with acute bronchitis in childhood (acute wheezy chest) or with chronic bronchitis in adults. In these cases wheezy breathlessness usually develops at the time of acute infection and may even persist and dominate the clinical picture.

Frequently the clinical type of asthma is not characteristic. An irritating cough, productive of a little visid mucus often accompanies the wheeze and at times may dominate the picture. Sputum is variable in quantity and is often more copious after the attack. Bronchial casts may be expectorated often with a very distressing cough. These casts may have worm-like appearance. The sputum in asthma may be purulent either as the result of an infection, less commonly, of a gross excess of eosinophils. Whereas bronchial casts and plugs are usually mucoid, with allergic aspergillosis brown plugs are expectorated : these contain mycelial fragments.

Status asthmatic is prolonged asthma, unrelieved by treatment, which may threaten life. In status asthmatics there is increasing obstruction of smaller airways by tenacious mucous plugs infiltrated with eosinophil. These plugs

tend to be laminated due to successive layering of mucus. Sometimes the mucus is aspirated peripherally and in fatal cases there is detachment of the superficial lining of the mucous membrance together with thickening of the basement membrance.

A spontaneous pneumothorax or massive collapse due to a mucous plug should be suspected with any sudden deterioration but the physical signs may be difficult to detect. Respiratory failure with a rise in the arterial Pco2 is usually a late event in severe asthma but may complicate the clinical picture earlier if asthma is superimposed upon chronic obstructive bronchitis.

1-3-5: Diagnosis:

The diagnosis of asthma is usually straightforward and is based on the history and examination and established by simple tests of ventilatory capacity (i.e. EEV, or PEF) before and after a bronchodilator.

Chest radiographs are usually normal in asthma although overinflation may be suggested by low diphragm.

The blood count in asthma may be normal or there may be an eosinophilia either in intrinsic or extrinsic asthma.

Sputum may contains excess of eoinnophils and characteristic casts of the smaller airways may be expectorated.

Tests of hypersensitivity. Skin testing by prick or intracutaneous methods using allergens of animal, vegetable, or microbiological origin may reveal specific, immediate, wheal and flare reactions to one or more of these agents. Approximately 10 per cent of a random population will react to one or more of these allergens -i.e. they are atopic subjects. Skin testing is chiefly of value in assessment of type of asthma- extrinsic asthmatics are usually atopic and react to more than one of these agents whereas patients with intrinsic

asthma tend to be non-atopic and react to one allergen or frequently to none. Skin tests do not correlate absolutely with bronchial reactivity to inhaled allergens but the results of skin testing are helpful in clarifying those allergic factors which may be responsible for the asthma -the history obtained from the patient remains the most important guide to these factors.

Tests of respiratory function. In particular those of ventilatory function (FEV_1, FVC, and PEF) are important in the diagnosis, for variability of airways obstruction is characteristic. A rise of more than 20 per cent in the FEV_1 or PEF may be expected to follow the inhalation of an aerosol of an adrennergic agent such as isoprenline in all but the most refractory cases.

1-3-6: Treatment:

Attacks of asthma usually respond to simple bronchodilate or drugs. Adrenergic drugs that simulate β- receptors and relax smooth muscle in the bronchial wall, are the most valuable agents.

Between attacks of asthma, precipitating factors should be eliminated as far as possible. Allergens will have been discovered by careful history-taking and skin tests. Environmental sources of allergens such as bedding, dust, and domestic animals, which precipitate attacks should be eliminated or controlled. Specific desensitisation by injection of increasing doses of allergens is of value only in some cases of pollen-induced asthma. It has been shown that crude extracts of house dust are not better than control injections in preventing asthma when there was established hyper sensitivity to the dust. The discovery of the house dust mite (dermatophagoides culinae) may lead to preparation of an effective means of desensitisation to house dust, but in general, specific desensitisation is of little or no value in the management of asthma.

Infection should be avoided particularly when there is a clear history of attacks precipitated by acute respiratory infection. Appropriate chemotherapy should be given and future episodes of respiratory infection treated immediately at their onset.

Psychogenic factors should be assessed and if possible remedied. Studies have shown that removal of children with asthma to a completely new environment may often relieve their symptoms.

1-3-7: Prognosis:

The prognosis for extrinsic asthma starting in childhood is good. The attacks usually cease later in childhood or adolescence, twice as often in boys. Adults free of asthma for years, however, may show a reduction in PEF or FEV1 or other tests of ventilatory capacity after exercise- this indicates a persistence of the increased reactivity. After periods of many years freedom from asthma attacks may start again in later life. The prognosis for extrinsic asthma is less certain in those that react to larger number of allergens.

The prognosis for intrinsic asthma which starts later in life is clearer. Over-all, 3 per cent of asthmatics die with increasingly severe asthma despite all measures. Bronchial infection, if it becomes established, adversely affects the prognosis too.

In the UK. there has been a recent increase in the mortality due to bronchial asthma in all age groups (from 1214 cases in 1959 to 2040 in 1966- an increase in death rate from 2.7 to 4.2 per 100,000 of the population). This increase was most striking in the age group 10-14 years and amounted to an eightfold increase. The reason for this increase in mortality was unknown but could not be attributed to the use of steroids. A later report indicated a fall in

mortality after 1966. In 1974 the figures were 1086 cases or 2.2 per 100,000. While this fall in mortality coincided with a drop in the sale of aerosol bronchodilator it is yet too early to be certain of the link between these two observations. Severe asthmatics, particularly in adolescence, require close supervision and rapid modifications of their treatment when attacks of asthma develop.

1-4: Literature Review :

The main difficulty in reviewing the literature of asthma admission was not the variety of methodologies that have been used.

We mentioned briefly in section 1-2, that the data set which is used for our research is unique. No other research is exactly similar to the ours. Other studies were different either in methodology or in type of data which was used. We could not find any study which analysed the first and the later admissions of one asthmatic separately. None of the previous studies has used the linked data or covered such a wide area as Scotland. Here the results of some studies, which are the most related ones to our study, are reported.

A research in New Zealand (Horwood L. J. 1991) "Admission patterns for childhood acute asthma, Christchurch 1974-1989" was carried out to examine the trends in hospital admission for acute childhood asthma in Christchurch over the period 1974-1989. In this study, trends in the asthma annual rates of admission and readmission for asthma were compared for boys and girls in each of three age groups : 0-4 years, 5-9 years and 10-13 years. The results show that for both sexes there was a 4.5-5 fold increase in overall rates of admission during the survey period. Boys on average had higher admission rates than girls (later we will show that this result does not apply to Scotland) with this effect being most marked in the pre-school age group. This research has shown that since the mid 1980's there has been a changing pattern of admissions with a downward trend in admission rates for school aged children and a continuing upward trend in the pre-school girls admitted with acute asthma. They have warned that there has been a rise in the numbers of pre-

school girls admitted with acute asthma: admission rates for this group had shown a three-fold increase since 1983.

Another study (Ehrlich R.I. 1994) was done in the Cape Town, South Africa to determine whether hospital admissions for acute childhood asthma were rising in Cape Town in line with the experience of other countries. Red Cross War Memorial children's hospital records for the period 1978-1990 were analysed. In this study, they compared these mentioned records of admissions with total admissions for non-surgical causes and lower respiratory tract illness as well as those for bronchiolotis and pneumonia. Asthma admissions showed a sharp upward trend from 1978 to 1984, a slower rise through 1987 and levelling off since. The profile of hospital admissions for respiratory illness was also analysed. Black children were under represented among asthma admissions compared with those for pneumonia. Asthma admissions occurred through the year but showed seasonal peaks in May and November.

Schwarts J. (1994) investigated the relation between air pollution and hospital admissions for the elderly has been investigated. One of these studies has examined the association between both PM10 and Ozone and respiratory hospital admissions for persons under 65 years of age or older in the Detroit, Michigan, metropolitan area during the years 1986 to 1989. It showed that asthma admissions were not associated with either pollutant. In other research (Edwards J. 1994) the relationship between residence near major roads, traffic flow and risk of hospital admission for asthma in children younger than 5 years age living in Birmingham, United Kingdom, was discussed. Area of residence and traffic flow patterns were compared for children admitted to the hospital for asthma, children admitted for nonrespiratory reasons, and a random sample of children from the community. This study showed that children admitted with an asthma diagnosis were significantly more likely to live in an area with high

traffic flow(>24,000 vehicles/24 hours) located along the nearest segment of main road than were children admitted for nonrespiratory reasons (P<.002). It reported that there is a significant linear trend for traffic flow (P<.006) for children living less than 500 m. from a main road but not for those living farther away. Children admitted for nonrespiratory reasons were more likely to be admitted than children in the community sample if they lived within 200 meter of main road (P<.02), irrespective of traffic flow.

Hyndman S.j. (1994) described trends in hospital admissions rates for asthma in England and Wales (1976-1985), the East Anglian region (from 1976 to 1991-2), and for Wales (1980-1990). This study showed that rates of asthma admission for England and Wales as a whole showed a steady upward trend throughout the period examined. Rates in East Anglia, though they were similar to the national trends in the early years, showed a peak in 1985 (for males and females) with some indication of a decline in rates thereafter. Rates for Wales showed an upward trend until 1988 (for both males and females) after which they showed a decline.

Some studies have reported the influence of age, sex, ozone, sulfates, air quality and prematurity (for babies) on asthma admissions.(Skobeloof E.M. 1992, Mayol P.M. 1991, Senthilselvan A. 1993, Von. Multius E. 1993, Frischer T. 1993, Abduelrhman E.M. 1992, Cody R.P. 1992, Christie D. 1992, Thurston G.D. 1994, Burnett R.T. 1994) In one of these studies the demographic data from a large population of asthmatic patients was used to define the role of age and sex as risk factors for asthma admission. In this study a retrospective review was undertaken of all asthma admissions as defined by Intentional Classification of Diseases , Ninth Revision, code 493.0. All medical-surgical admissions from 67 hospitals in five counties of south-eastern Pennsylvania from 1986 through 1989, are the data which was used by this study. The

patients admitted for asthma treatment (33,269) were reviewed and it was shown that in the 0-5 years old and 6-10 years old age groups, males were admitted nearly twice as often as age identical females. In the 11-20 years old age group, admissions for males and females were nearly identical. Between 20 and 50 years age, the female-to-male ratio was nearly 3:1. Thereafter, females were admitted for asthma at a rate of about 2.5:1 when compared with their age-equivalent male counties. They reported also that the length of stay in hospital increased proportionally as the patient age increased but after 30 years of age, the length of stay was slightly greater for females than males (Skobeloof E.M. 1992).

In some other studies the relation between the asthma admissions and school holidays have been investigated.(Storr J. 1989) In one of these studies the admission rate for asthma at a children's hospital was studied over an 11 year period. The study showed the admissions varied unpredictably over periods of a few days, but there was a repeated yearly pattern of peaks and troughs with an interval of several weeks. The study suggested that the short term variation could be attributed to chance effects alone, excluding any important role for short term influence (for example weather changes)in precipitating asthma admissions. It has reported a definite association between the longer term variation and the school holidays. The admission rate fell during holidays and there were two or more peaks during terms. They mentioned that the pattern of asthma admission was consistent with a largely viral aetiology for asthmatic attacks throughout the year. They postulated that school holidays disrupt the spread of viral infections in the community, with synchronisation of subsequent attacks. Travel during holidays may facilitate acquisition of new viral strains by the community.

One study which has carried out in Blackburn, United Kingdom, has reported that in year 1987 the rate of asthma admissions in ethnic Asians was more frequent than expected (Myers P. 1992). It was claimed that the increased admission rate in Asians was not due to increased readmissions in the Asian ethnic group and it has been suggested that the difference in Asian admission rate may be due to a truly increased asthma prevalence in the Asian ethnic group.

In a study in New Zealand (Mitchell E.A. 1994) the risk factors for asthma readmissions to hospitals in childhood has been discussed. This study was an observational study and recorded demographic features and the severity, treatment and management of asthma in 1034 individual children admitted to hospital over a one year period, followed for maximum of 33 months. It reported that readmissions were common, with 33% readmitted by 6 months and 51% by two years. In this study it was claimed that, after controlling for wide range of variables, factors that significantly increased readmission were : female sex, young age (age<5 years), number of previous admissions, and inpatient intravenous treatment. It has been reported that medical treatment and management did not influence readmissions. A high readmission rate in childhood was reported by this study.

Another study among the American Indian and Alaskan native children was carried out to discover the trends in asthma-related admissions from 1979 to 1989. In this study, the hospital discharge records of patients aged 17 years and younger treated by the Indian Health Service between 1979 and 1989 have been used as the data. The rates of asthma-related hospitalisations was shown to have increased by an average of 2.6% per year between the 1979 and 1989 among American Indian and Alaskan Native children aged 0 to 17 years. The increase was 3.7% among the 0 to 4 year age group and 0.3% among the 5 to

17 year age group. It was reported that boys tended to have a higher rate of increase (4.3%) compared with girls (2.6%) (Hisnanick J.J. 1994).

There are some researches which have used linked data to study asthma readmissions. All of these studies, if done in UK., have used a linked data of admissions which we mentioned before and belongs to Oxford district. The Oxford linked data set contains all admissions of all patients in Oxford district between years 1968 to 1985.(Goldacre M.J. 1988, Heasman M. A. 1968, Henderson J. 1989, Acheson E.D. 1967, McPherson K. 1985) In some of these studies, it has been shown that the asthma readmission rate within 28 days of discharge from elective readmission (unplanned readmission) rose in Oxford area from 3.5% in 1968 to 7.1% in 1985, more than doubling in about 18 years.(Henderson J. 1989) In another study it is claimed that there is about 80% of a cumulative increase in asthma admissions over past ten years and it is a reason to believe that the number of patients who were admitted to hospitals have also increased. This study reported about 20% rise in multiple admissions per person per year.(Goldacre M.J. 1988)

Hodkinson and Hodkinson (1984) designed their study on asthma admissions to Hammersmith hospital in London and have shown that in one year follow up 36% of all admissions to their Geriatric Department were readmission. They found that there was no significant difference between sexes and readmitted patients were significantly older and more likely to have been inactive before admission but were less often dehydrated or constitutionally upset. Significantly more readmisions came from old people's homes.

Another study related to readmission of elderly patients belongs to Idris Williams and Freda Fitton and was carried out in a district general hospital in Nottingham. They have shown that unplanned readmission rate within 28 days of discharge was 6% and planned readmission rate was 3%. It was thought that

unplanned readmission was avoidable for 59% of patients.(Williams I.E. 1988) According to their study, low income was an important factor of readmission and there was no correlation between living accommodation and unplanned readmission. They listed seven possible principal reasons for readmission of elderly of which the most important one is relapse of the original medical conditions.(Wiliams I.E. 1988)

Another study that has been for elderly readmission in Wales in 1981, showed that within 3 months of discharge, 17% of patients being readmitted as in-patients, and the proportion of readmissions did not vary significantly with age or sex of patients. Similarly there was no statistically significant difference between those living alone compared with those living in larger households.(Kendrick S. 1992)

Some other studies were carried out to discover the readmission rates abroad (Kendrick S. 1992, Leibson C.L. 1991, Newcom R.W. 1986, Baribean-Braun J. 1979, Safran C. 1989, Ashton C.M. 1987, Hisnanick J.J. 1994). One of these studies was in Rochester, Minnesota in USA (Leibson C.L. 1991). In this study which is related to years 1970 to 1987, the authors know that the admissions have begun to moderate because of using a new system of payment, the "Post Prospective Payment System", but they were keen to know whether the declines in admissions were a result of fewer individuals being hospitalised or fewer rehospitalisations of the same individuals. They calculated readmission rates using linked data and found risk factors for and pattern of readmission in the area. They showed that a 4.6% decline in the number of persons 65-74 years age who were hospitalised/10000 population from 1980 to 1987 was offset by 17.1% increase in the number of rehospitalisation/1000 population of this age group. In addition, they discovered that the number of rehospitalisations/1000 population for the age group>75 increased 5.7% from

1980 to 1987, and the proportion of country Olmsted county residents >75 years of age who were hospitalised at least once the year increased 8.3% (Leibson C.L. 1991).

In a study which has been carried out in Glasgow, the management of asthma has been discussed. It showed that asthma is often poorly treated in general medical units, with inadequate attention being paid to the importance of pre-existing poor control, and to the continuing close supervision of patients in the acute phase of their disease (Buck Nail C.E. 1988). In another study in Edinburgh it was shown that 49 patients were responsible for 104 admissions. 49% of admissions were that of patients between the age of 15 to 20 years and multiple admissions were much more common in the self-referral group (Forwell M.A. 1985). A report from "Edinburgh Emergency Asthma Admission Service", has noticed that during a 15-year period, 195 asthmatic patients were responsible for 873 hospital self-admissions (Crompton G.K. 1987). Over the 15-year period, during the last 3 years there were significantly more night admissions than during the first 3 years (Crompton G.K. 1987).

From 1978 to 1985, admissions for childhood asthma among 5-14 age group increased by 56% whereas admissions for bronchitis decreased by 20% in the UK. (Anderson H.R. 1989). Readmission rate has fallen slightly from 1.47 to 1.32 from early 1970'syndrome to 1985 (Anderson H.R. 1989). In another study it was reported that rates of admission for childhood asthma in England and Wales have more than doubled since the mid-1970's (Anderson H.R. 1989). A 167% rise in childhood asthma admission in South West Thames region (Brighton) between 1970 and 1978 has been reported by Anderson et al (Anderson H.R. 1980).

Chapter 2

Descriptive and Initial Analyses

In this chapter first we mention the modifications which were done to prepare the available data set for analyses. First we explain these modifications in as much detail as possible. Second, we intend to describe the pattern of asthma admissions by illustrating some simple tables and charts. Later some discoveries, which may be important and are based on the descriptive analyses, are reported. Some of these discoveries may be used later when some more precise analyses will be carried for both first and later asthma admissions.

2-1 : Creating the data file for analyses (Modifications on the initial data set)

The data that was described in section 1-2, was not ready for analyses. Some important modifications were therefore done to find some aggregate covariates and also to delete some records which were not related to asthma disease. The number of records in the original data file were 249559. As was mentioned before, the original file contained all admissions -whether or not related to asthma- belonging to all patients who had been hospitalised, at least

once, in one of Scotland's hospitals with asthma diagnosis -either first or second diagnosis- between the years 1981 to 1992. The main modifications that were done were, i) creating new covariates -by using the records that we intended to delete-, ii) identifying the first admission and iii) deleting unnecessary records.

First of all, we ran a FORTRAN program and considered all records that belonged to transferred admissions as a single record, i.e. if one asthmatic patient, during one of his/her admissions, has been transferred from one speciality to another speciality or from one hospital to another hospital , we considered all these kind of recorded admissions as a single admission. We insert the values of explanatory variables in the first previous record which was not a transferred record as the information for the new created record.

Secondly, we ran another FORTRAN program and we counted for each asthmatic patient all his/her non-asthma admissions which had occurred between two asthma admissions. We saved also for each of the last four of these admissions (i.e. non-asthma admissions) the speciality code and the date of admission (year, month and day). All these new variables were saved in the second related admission to asthma i.e. after running the program, for any asthmatic patient, each admission that was related to asthma had information about the admissions that had accrued before this admission and which had not been related to asthma. If the admission that was related to asthma was the last admission of asthmatic patient (and some non-asthma admissions had occurred after it), then the information about his/her later non-asthma admissions was saved in this last record as new variables. After running this program, all records (i.e. all admissions) for which neither their first diagnosis (i.e. first reason of hospitalisation) nor their second diagnosis (i.e. second reason of hospitalisation) was related to asthma (i.e. the diagnosis code was not 4930,

4931 or 4939), were deleted. Hence all remaining records are asthma admissions (according to first or second diagnosis) and in each of them, in addition to the originally explanatory variables, there is information about the previous non-asthma admissions that had occurred after the immediate previous asthma admission. If the asthma admission is the last asthma admission of the patient, then the information about the later non-asthma admissions was saved in this last asthma admission as new variables.

Third, we ran another program to create some more explanatory variables. At this stage, 5 new variables were created for each asthma admission. These were, order of asthma admission (for the asthmatic patient), length of stay in hospital, time free of admission and two indicator variables one of which identifies whether the time free of admission is complete or censored and another identifies whether the asthma diagnosis is the first or second diagnosis. It is important to mention that before calculating the time free of admission, we investigated whether the asthmatic patient had died before the end date of follow up. If so, his/her last time free of admission was calculated up to the date of his/her death.

Fourth, it was decided to use one part of the data file to support the another part to identify the first asthma admission of each asthmatic patient from his/her first recorded asthma admission. Note that the first recorded asthma admission of any asthmatic patient which exists in the data file, is not necessarily his/her first asthma admission to hospital. The reason is that some patients might have some asthma admission to some hospitals throughout Scotland before our follow up began (i.e. before 1/1/1981) in which some asthma admissions of such patient will be missed. The first recorded asthma admission of such asthmatic patients is therefore not their first asthma admission. Note that if the data file is analysed without identifying the first

asthma admission of the asthmatic patients or without being sure that a particular asthmatic patient has not had any asthma admission before 1/1/1981, no one can guarantee that the complete pattern of asthma admissions of asthmatic patients has been studied. To identify the first asthma admission of each asthmatic patient from his/her first recorded asthma admission, the data file was divided into two parts. One part contained all asthma admissions which occurred from 1/1/1981 to 31/12/1983 and the other part contained those asthma admissions which occurred from 1/1/1984 up to end date of follow up (i.e. 31/12/1992). The first recorded asthma admission of each asthmatic patient in the second part of the file was chosen and it was checked whether this asthmatic patient had or had not any previous asthma admissions in the first part of the data file. If no asthma admission was found in first part of the data file, then the first recorded asthma admission (in the second part of the data file) was considered as the first asthma admission, otherwise it was concluded that the first recorded asthma admission (in the second part of the data file) is not the first asthma admission. All admissions of such patients whose first recorded asthma admission in the second part of the data file was not their first asthma admission to hospital were deleted from the second part of the data file. Finally we chose the second part of the data file as the final data set which all analyses are based on. Note that, in this new data file, each asthmatic patient has been followed up at most for 9 years (from beginning of 1984 to end of 1992) and at least for 3 years (and at most for 12 years), no previous asthma admission before the first recorded asthma admission (which was chosen as the first asthma admission) has occurred for the asthmatic patient. Later, in section 2-2, the accuracy of this method in identifying the first asthma admission will be discussed. Hence the whole pattern of asthma admissions of each asthmatic patient exists in this new data file i.e. all asthma admissions (from first

admission because of asthma to last admission up to end of follow up) of the asthmatic patients are examined.

As the result of the above procedures, the file which is the basic file for all analyses, contains 69,814 asthma admissions (with either first or second diagnosis as asthma) belonging to 40,496 asthmatic patients whose first asthma admission (i.e. first hospitalisation) occurred between year 1984 to 1992.

Later, for analysing the pattern of later admissions of the asthmatic patients (i.e. the asthma admissions which occur after the first asthma admission), it was decided to consider each asthmatic patient's later asthma admissions in a 3 year horizon after the first asthma admission. Some more modifications were carried out on the basic data file to count the number of later asthma admissions of each asthmatic patient in the 3 years after his/her first asthma admission. In analysing the pattern of later asthma admissions, only the effect of explanatory variables at time of first asthma admission on the pattern of later asthma admissions was studied.

2-2 : Investigating the precision of a 3 year support for identifying the first asthma admission :

As was said in 2-1, one of the most important modifications on the initial data set was to identify the first asthma admission from the first recorded asthma admission. To do so, the asthma admissions' information in years 1981 to 1983 (3 years) was used. It was mentioned that those asthmatic patients who are included in the final data set and whose first recorded asthma admissions have occurred in year 1984 have a 3 years of support that their first recorded asthma admission is their first asthma admission. Hence as the patients' date of first recorded asthma admissions increases, the time support for distinguishing between the first recorded asthma admission and first asthma admission also increases. Note those asthmatic patients who are included in the final data set and their first recorded admissions have occurred in, for example, year 1992, have a 12 years.

There are some asthmatic patients of which we are confident that their first recorded asthma admission is their first asthma admission. These are the asthmatic patients who are less than 3 years old. To be more precise, we are confident that the first recorded asthma admission of the asthmatic patients whose age is at most equal to the time interval between their admission date and the date 1/1/1981 (i.e. their support time interval for identifying the first asthma admission) are really their first asthma admission. The reason is that these asthmatic patients have been observed since they have been born, therefore if they had any asthma admission it should have been already recorded. For example, we are confident that, an asthmatic patient whose first

recorded asthma admission has occurred in the year 1992 and is at most 11 years old, has been hospitalised, for the first time with asthma.

We now present an assessment of the adequacy of our choice of 3 years for distinguishing the first recorded asthma admission from the first asthma admission. The first time free of admission of the asthmatic patients was used to investigate how many of asthmatic patients return to hospital after 3 years. We remind the reader that the first time free of admission of an asthmatic patient is defined as the time interval between his/her first discharge (i.e. the discharge due to first admission) date from hospital and the date of his/her second admission. Since some asthmatic patients may not have second asthma admission (until the end date of the follow up), some of the first times free of admissions will be censored. Note that we are interested only in complete times free of admission because it is intended to estimate the cumulative proportion of the asthmatic patients who return to hospital within 3 years after first discharge given the patients have returned to hospital (the second asthma admissions have occurred). In this case (by deleting the censored first times free of admission) both the life table method and simple frequency table are equivalent. Table 2-2-1 shows the proportion and the cumulative proportion of asthmatic patients who return to hospital in different time intervals after the first discharge from the hospitals. The table indicates that nearly 90% of the asthmatic patients return to hospital within 3 years after first discharge. The proportion of the asthmatic patients who return to hospitals within 4, 5, 6 and 7 years after first discharge are, respectively, 94%, 97%, 98.5% and 99.4%. Table 2-2-1 confirms that the choice of at 3 least years (1981-1983) as the support for identifying the first asthma admission is adequate. Note that the asthmatic patients who are included in the final data set, have been observed on average for 7 years before their first recorded admission (varies from 3 years

for those whose first recorded asthma admission occurred in the year 1984 to 11 years for those whose first recorded asthma admissions occurred in the year 1992). Together with the fact that 99.4% of the asthmatic patients have their second asthma admission within 7 years after first discharge, it confirms that generally the first asthma admissions have been distinguished from the first recorded asthma admission correctly. We remind the reader that this indication has come from studying the first times free of admission and if one considers other times free of admission then different results may be found. However, we have examined also second times free of admission and obtained similar results.

Table 2-2-1 : Frequency of number of asthmatic patients in different time intervals from first discharge. For those who have returned to hospitals.

Time interval from first discharge	**No. of asthmatic patients**	**Percent %**	**Cumulative percent**
up to 1 year	7762	65.7	65.8
2 years	1884	16.0	81.7
3 years	912	7.7	89.4
4 years	547	4.6	94.1
5 years	322	2.7	96.8
6 years	196	1.7	98.5
7 years	117	1.0	99.4
More than 7 years	65	0.6	100
Total	11805		

2-3 : Descriptive analyses of first asthma admissions :

In this section the first asthma admissions of the asthmatic patients are used to illustrate the frequency of number of first asthma admissions in different factors. These are all asthma hospitalisations due to new asthmatic patients in years 1984 to 1992. During these years, 40,496 asthma hospitalisations due to new asthmatic patients occurred in Scotland i.e. on average, 4,500 events per year. Note that there could be more new asthmatic patients in these years who might be treated as outpatients. However since they have not been hospitalised (as inpatients) in any hospital in Scotland, (maybe because their asthma disease has not been serious) they are not included in our data set. We mentioned also that 6,132 of the above admissions are due to those new asthmatic patients having asthma as their second reason of hospitalisation. Note that such patients might either have asthma or some other respiratory disease which is related to asthma or not have asthma at all.

Plots 2-3-1 to 2-3-13 shows the number of first asthma admissions between years 1984 to 1992 by age group, sex, marital status, where admitted from, admission type, year of admission, month of admission, day of admission, discharge code, category of patients, type of facility, speciality, type of diagnosis and city. There is not so much to say about these plots. Actually these plots are reasonably self explanatory. Note that since the size of the population, at each level of each factor, at risk of asthma admission is unknown, it is not possible to use most of these plots to show the prevalence of asthma admissions. Such factors are, for example, age group, city and marital status. However, for sex it is possible to interpret the percentages of number of first admissions in males and females as their prevalence rate of asthma

hospitalisation. This is because it is reasonable to believe that males and females are equally distributed in the population. Plot 2-3-2 indicates that males are more at risk than females to be hospitalised as new asthmatic inpatients. Plot 2-3-6, which shows the number of first asthma admissions in different years of first admission, indicates some important and interesting trends in occurring the first asthma admissions. We will discuss it later in section 2-5.

We omitted plots for "type of asthma" identifying whether the type of asthma is diagnosed as acute or chronic, due to the discovering that this factor has invalid information. In a later section we discus this factor in more detail and show that differences in the number of first asthma admissions for different levels of this factor is really due to differences in the fashion of diagnosis in different cities. This important discovery is reported in section 2-6.

An important conclusion from the above plots is that for some factors such as "admitted from", "discharge code", "category of patient" and "type of facility", nearly all first asthma admissions are due to only one level of the factor. Plots 2-3-4 and 2-3-8 to 2-3-10 show that nearly all first asthma admissions are admitted from home, are discharged to home, have been using NHS free treatment and have been admitted as inpatients. These 4 factors are not practically useful in relation to first asthma admissions and so will not be analysed further.

Plot 2-3-7 shows the number of first asthma admissions in different months of the year. The plot suggests that in some months of the year, September, October, November and partly in December, in comparison to other months, more first asthma admissions occur. Two peaks exist in the plot which are due to March and September. Plot 2-3-7 actually indicates the existence of

a seasonal pattern in the number of first asthma admissions which will be discussed later in section 2-4.

We remind the reader that while the postal areas Aberdeen, Dundee, Edinburgh and Glasgow consist of those cities and their natural winterlands, Kilmarnock approximates to Ayrshire (including Arran).

2-4 : Seasonal Changes in occurrence of first and later asthma admissions :

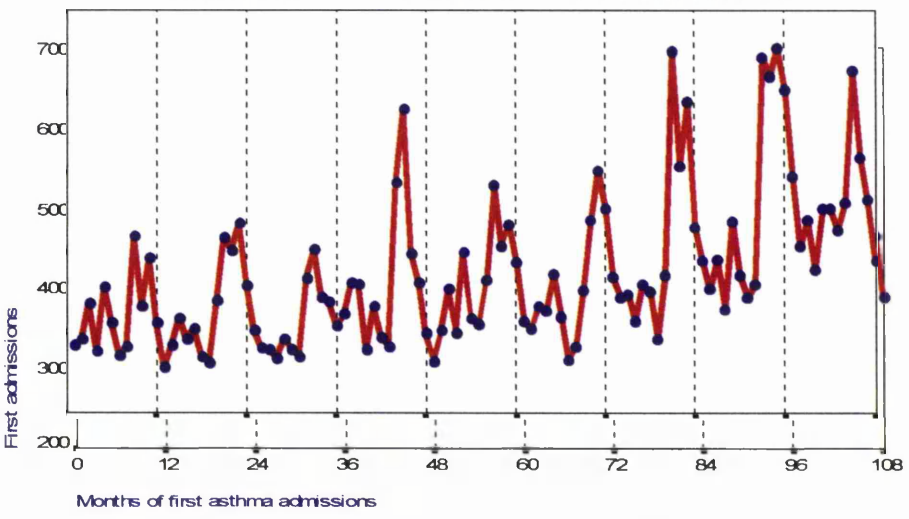
Seasonal changes in asthma admissions have been reported by several authors. In none of these reports have first and later asthma admissions been separated. In this section we illustrate the seasonal pattern in occurrence of both first and later asthma admissions in the Scotland over the years 1984 to 1992.

Plot 2-4-1 shows the numbers of first asthma admissions in all Scotland's hospitals in each month from January 1984 to December 1992. There are usually two peaks in each year. One in around March and another one in September. The number of asthma first admissions around July is usually the lowest. The plot suggests that after July, the number of first asthma admissions increases and in last 3 (and sometimes in last 4) months of each year it takes the highest values.

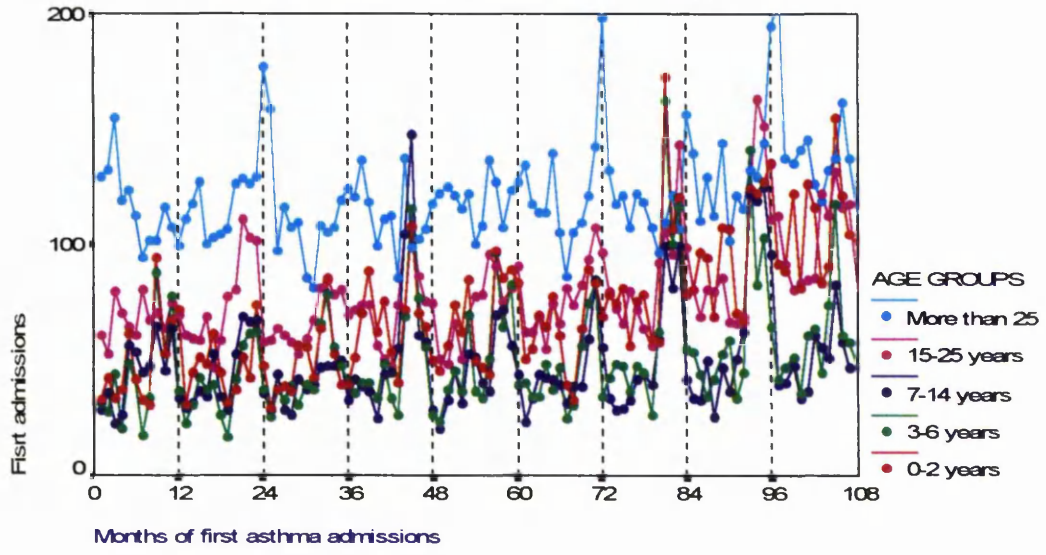
Using the plot 2-4-1, it is possible to compare the changes in seasonal pattern of first asthma admissions in years 1984 to 1992. Note that the seasonal changes in the years 1984 and 1985 are quite similar. Similar seasonal changes have happened in years 1990, 1991 and even 1992, but the second peak (The peak around September) is clearly higher than the similar peak in previous years. It suggests that in these recent Septembers, Octobers and Novembers, more asthma admissions (as the first ones) have happened compared to the similar months in first years of follow up. One can see an increasing trend in number of first asthma admissions in the later years.

Plot 2-4-2 has been prepared to investigate whether the seasonal pattern of first asthma admissions is or is not different in different age groups. As the patterns due to different age groups are seen to be very close it is difficult to interpret this plot. This plots suggests that some clear changes in the seasonal pattern of those asthmatic patients who were over than 25 years old, has happened over the years 1984 to 1992. This group of asthmatic patients

Plot 2-4-1 : Numbers of first asthma admissions to Scotland's hospitals

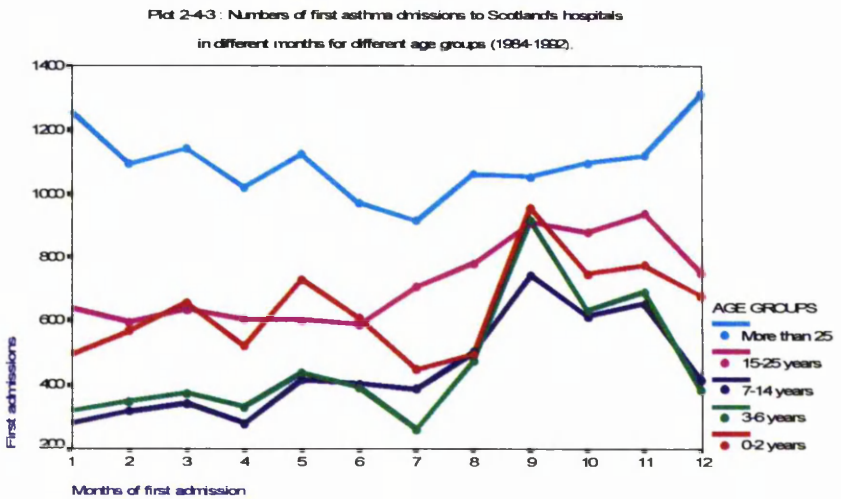


Plot 2-4-2 : Numbers of first asthma admissions to Scotland's hospitals in January 1984 to December 1992. In different age groups.



appears not to have a peak around September at all. Instead the peak is either in December (years 1985, 1989 and 1991) or not at all. All seasonal patterns (due to different age groups) suggest that the peaks around September and October in the later years of study are higher than the peak in the first year of study.

Plot 2-4-3 shows the number of first asthma admissions over years 1984 to 1992 according to month of the year. Note this plot is actually an aggregated version of the previous plot, for example all first admissions in January (over the 9 years 1984 to 1992) have been aggregated considered as a single month. This allows an overall idea of seasonal pattern of first asthma admissions to be obtained. This plot suggests that number of first asthma admissions for the asthmatic patients who are more than 25 years old is maximum in January and December and its trough happens in July. The plot indicates that the maximum number of first asthma admissions for children (up to 14 years old) happens in September and for patients who are 15-25 years old in November.

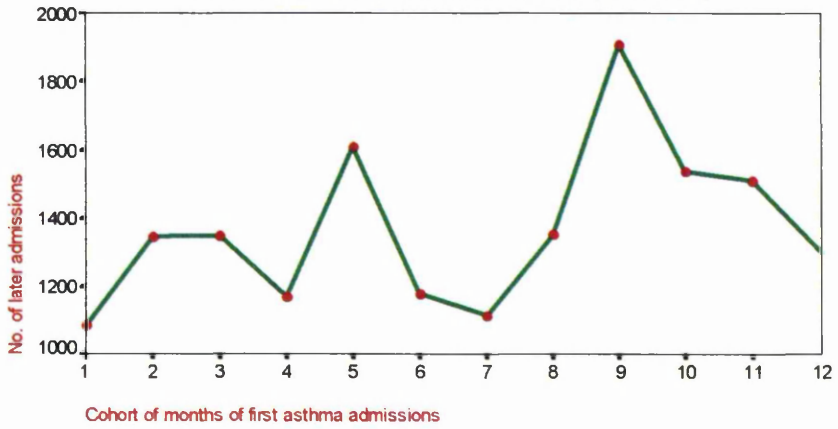


In previous paragraphs in this section we illustrated the seasonal pattern in number of first asthma admissions. Here we show the differences (if there are any) in number of later asthma admissions of the asthmatic patients whose

first asthma admissions have occurred in different months. We restricted ourselves to consider the number of later asthma admissions only in a 3 years horizon after first asthma admission. The reason for this decision will be discussed more precisely in section 2-5 where the trends in later asthma admissions over years 1984 to 1989 is going to be studied. We mentioned it here since as the number of later asthma admissions of each asthmatic patient is going to be considered in a full 3 years after the first asthma admission, it is only possible to include only those asthmatic patients whose date of first asthma admissions are up to end of year 1989 i.e. we can consider only cohorts of later admissions with first admission in the years 1984 to 1989.

Plot 2-4-4 shows the number of later asthma admissions in a 3 year horizon after first admission in different cohorts of month of first asthma admission. Note this plot misleads the reader if being used to report occurrence of more later asthma admissions for those asthmatic patients whose month of

Plot 2-4-4 : Numbers of later asthma admissions to Scotland's hospitals in each cohort of month of first admissions (1984-1989).



first asthma admission is in September. The reason is this can be simply a reflection of having more first asthma admissions in this month. To investigate whether the number of later asthma admissions due to some cohorts of months

of first asthma admission is or is not more or less of the number of later asthma admissions in some other cohorts, plot 2-4-5 was prepared.

Plot 2-4-5 shows the ratio of "number of later asthma admissions in a 3 year horizon after first asthma admission" to "number of first asthma admissions" in different cohorts according to month of first admission. Note it

Plot 2-4-5 : Ratio of No. of later asthma admissions in a 3 year horizon after first ad. (1984-89) to No. of first admission, in different cohorts of months of first admission.

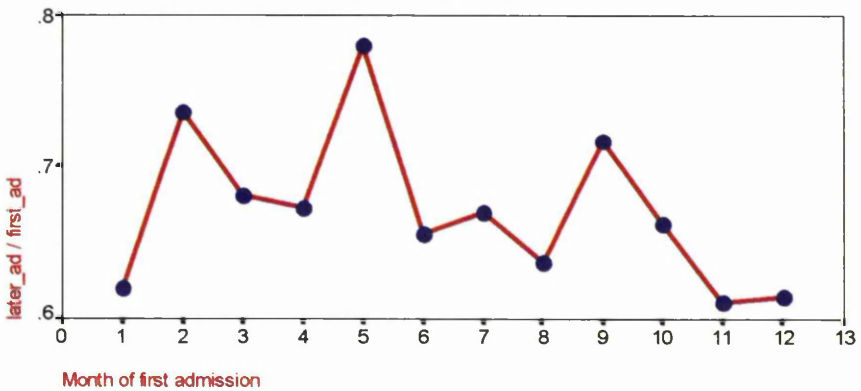


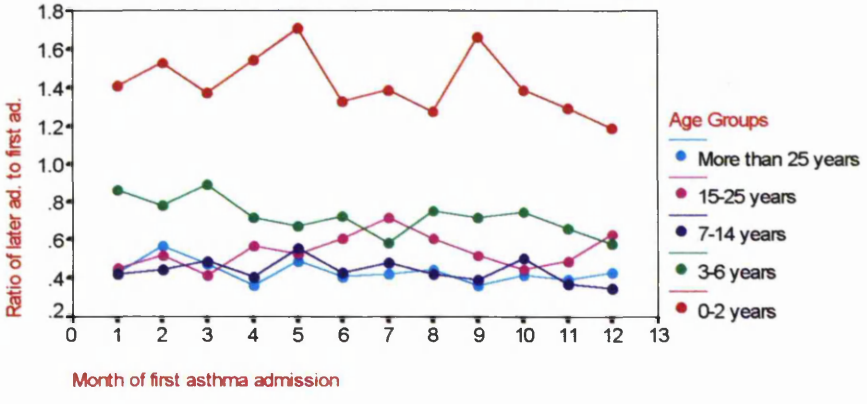
Table 2-4-1 : Chi-square test for comparing the numbers of later asthma admissions in a 3 year horizon after first admission with the expected number of later admissions in different cohorts of month of first admission.

Cohort of first admissions	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\Sigma(o_i-e_i)^2/e_i$
January	1747	1085	1174	6.69
February	1831	1349	1230	11.51
March	1982	1350	1331	0.26
April	1743	1172	1171	0.00
May	2062	1611	1385	36.81
June	1795	1177	1206	0.69
July	1665	1115	1119	0.01
August	2129	1357	1430	3.75
September	2661	1909	1788	8.25
October	2327	1541	1563	0.32
November	2471	1511	1660	13.37
December	2122	1305	1425	10.19
	24535	16482	16482	X^2=91.83, df=11 P<0.0001

is possible to use this plot to investigate whether the asthmatic patients whose month of first admission is a particular month return to hospital more frequently. Table 2-4-1 shows that the ratios in different cohorts of month of first admission are significantly different (P<.0001). This table indicates that patients whose month of first admission is in February or May are more likely to return while those whose month of first admissions are November or December are less likely to return to hospital.

To obtain a more clear idea about the relation between the number of later asthma admissions and cohort of month of first admission, plot 2-4-6 was prepared. This plot is similar to 2-4-5 but has been prepared for different age groups. Plot 2-4-6 indicates that among babies (0-2 years old), those whose month of first asthma admission is in May or September, are more likely to return to hospital more frequently whilst among those who are 15-25 years old, those whose month of first asthma admission is in July, are more likely to have more later asthma admissions.

Plot 2-4-6: Ratio of No. of later asthma admissions in a 3 years horizon after first admission (1984-89) to No. of first asthma admission in different cohorts of months of first ad. For different age groups.



2-5 : Trends and rates of first and later asthma admissions over years 1984 to 1992:

In recent years there have been a number of reports which claimed that asthma admissions to hospitals have been steadily increasing. In none of these reports has it been clear whether this increase corresponds to new asthmatic patients or is due to previously known asthmatic patients. In most of these reports only admissions to a single hospital or a single city have been considered. In this section we illustrate the trends in first asthma admissions (i.e. either new asthmatic patients or first serious asthma attack) and later asthma admissions over years 1984 to 1992.

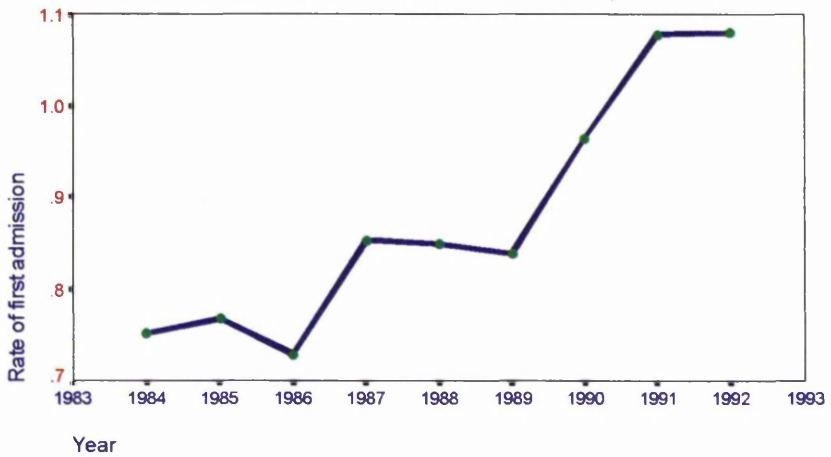
In years 1984 to 1992, in overall, 40496 first asthma admissions have happened. These patients have caused 29311 later admission, 0.72 later admission per patient. The average rate of first asthma admission in Scotland, in years 1984 to 1992, is 0.88 per 1000 population[1]. This rate varies considerably in different age groups. Table 2-5-1 shows the rate of asthma first admission in different age groups and different years. This table indicates that babies (0-2 years old) are 9.8 times more than adults (more than 25 years old) at risk of being admitted to hospital with asthma diagnosis as the first time. As age increases the hazard of being admitted with asthma diagnosis decreases. Table 2-5-1 also indicates that the rate of first asthma admission in year 1992 is 1.08 per 1000 population which is 1.4 times of related rate in year 1984.

Plot 2-5-1 shows rates of first admissions for asthma in the years 1984 to 1992. This plot indicates a sharp increase in years 1987, 1990 and 1991. The

[1]Population sizes (in different years, age groups and sexes) are estimated populations and are obtained from Annual Reports (1984 to 1992), Registrar General Scotland.

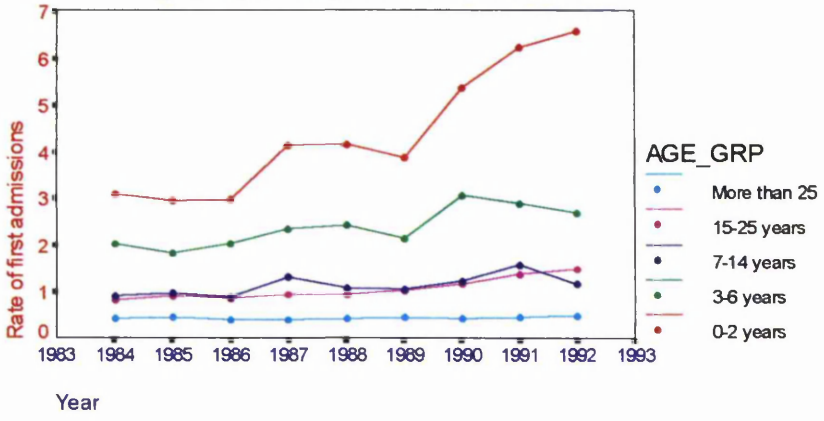
important implication of this plot is that even though the rate of first asthma admissions have increased over the period of study but it has not been increasing steadily. There are actually two or three jumps in mentioned rate, one in between year 1986 and 1987, one in between years 1989 and 1990 and the third one between 1990 and 1991. These jumps may relate to changes in some policies, for example changes in hospitals' hospitalisation policy, rather than to any real change in the severity of the disease. Overall, during the years 1984 to 1989, increases in rate of first asthma admissions in Scotland were minor, only around 0.1 per 1000 population. The important increase in mentioned rate is during years 1989 to 1991.

Plot 2-5-1: Rates of first admissions for asthma, 1984 to 1992.



Plot 2-5-2 shows the rates of first asthma admissions in different age groups. This plot was prepared to discover whether the rates of first admissions varies by age group. Plot 2-5-2 suggests that the rates of first asthma admissions is considerably different in different age groups. The most considerable, and maybe the only, increase is due to babies age group (0-2 years old). In this age group, the rate of first asthma admission in year 1992 is

Plot 2-5-2: rates of first admisions in different age groups, over years 1984 to 1992.



more than twice of it in year 1984. Note that in two age groups 3-6 and 7-14 years old, which are due to children asthmatic patients, rates of first admission have not changed considerably. In 3-6 years old children, it increased from 2.05 first admission per 1000 population in year 1984 to 2.71 in year 1992. The rates of first admission for all age groups are presented in table 2-5-1. Hence

Table 2-5-1 : Numbers and rates (per 1000 population) of first asthma admissions in different age groups over years 1984 to 1992.

Year	0-2 years old	Rate	3-6 years old	Rate	7-14 years Old	Rate	15-25 years old	Rate	More than 25 years	Rate	Total	Rate
1984	604	3.12	524	2.05	528	0.93	820	0.85	1400	0.44	3876	0.75
1985	571	2.97	481	1.84	544	1.00	890	0.93	1466	0.46	3952	0.77
1986	582	3.00	535	2.05	475	0.91	821	0.86	1328	0.42	3741	0.73
1987	813	4.14	607	2.36	688	1.34	901	0.96	1353	0.42	4362	0.85
1988	824	4.18	622	2.45	558	1.10	880	0.96	1445	0.45	4329	0.85
1989	760	3.89	552	2.16	538	1.07	929	1.05	1496	0.46	4275	0.84
1990	1046	5.37	796	3.09	636	1.26	1030	1.19	1424	0.43	4932	0.97
1991	1207	6.23	760	2.90	806	1.60	1149	1.38	1582	0.48	5504	1.08
1992	1289	6.60	706	2.71	604	1.18	1224	1.51	1702	0.51	5525	1.08
Total	7696	4.39	5583	2.40	5377	1.15	8644	1.06	13196	0.45	40496	0.88

even there is slight increase in rate of first asthma admission in age group 15-25 years but since it has increased steadily therefore it may be important. There is no change, or very small change, in rates of first admission over years 1984 to 1992 for adults.

Table 2-5-2 shows the numbers and average rates (per 1000 population) of first asthma admission (over years 1984 to 1992) in different sexes for different age groups. This table indicates that, male children (first 3 age groups) are more at risk of first admission than female children (first 3 age groups) while for adults it is reverses, i.e. for two last age groups female are at more risk than males. A male baby is 2 times of a female baby at risk of being admitted to hospital as first time. Plot 2-5-3 shows the pattern of rates of first admission for males and females in different age groups.

Table 2-5-2: Numbers and average rates (per 1000 population) of first admission in different sexes and age groups, years 1984 to 1992.

	Male		Female	
	No.	**Rate**	**No.**	**Rate**
0-2 ->years	5233	5.83	2463	2.88
3-6 years	4392	3.69	2170	1.91
7-14 years	2819	1.17	1579	0.69
15-25 years	1749	0.42	2620	0.66
More than 25	7078	0.52	10393	0.67
Total	21271	0.96	19225	0.81

Plot 2-5-3: Rate of first asthma admissions in Scotland for male and female in different age groups.

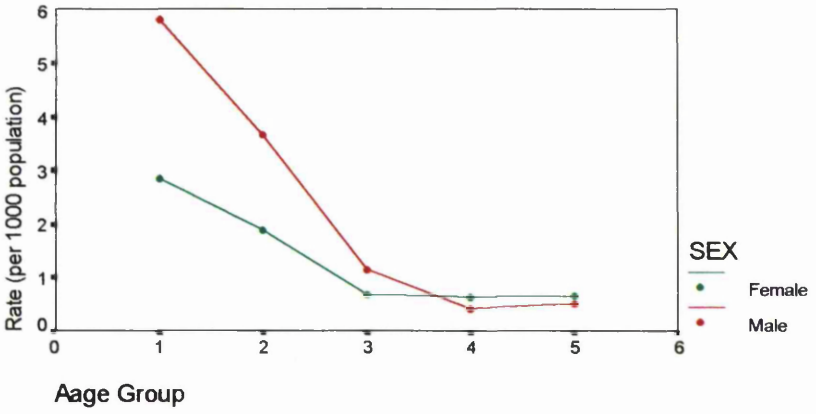


Table 2-5-3 shows the numbers and average rates (over years 1984 to 1992) in different cities of Scotland. The 7 cities which are considered here are the cities with most numbers of first admission. In finding the populations of these cities it is needed to explain that since we had used the post codes to create the cities, the boundaries of cities are different from what is usually called as administrative areas or cities. We understood that even the estimated populations of these cities, in between census years, do not exist. Therefore we approximated the populations by comparing the maps of post codes and administrative areas. These two maps and a list of administrative areas which are considered as a single city, are presented as "Appendix 2" at end of the thesis. To find the populations we used the estimated populations in years 1984 to 1992 (Annual Reports, General Registrar Scotland, 1984 to 1992) to pool or to exclude some administrative areas to approximate the populations for cities as we have defined. Table 2-5-3 indicates that two cities Dundee and Edinburgh have the highest average rates (1984-1992) of first asthma admissions in Scotland. Paisley has the lowest rate. Plot 2-5-4 shows the pattern of changes in rates of first asthma admissions in different cities over

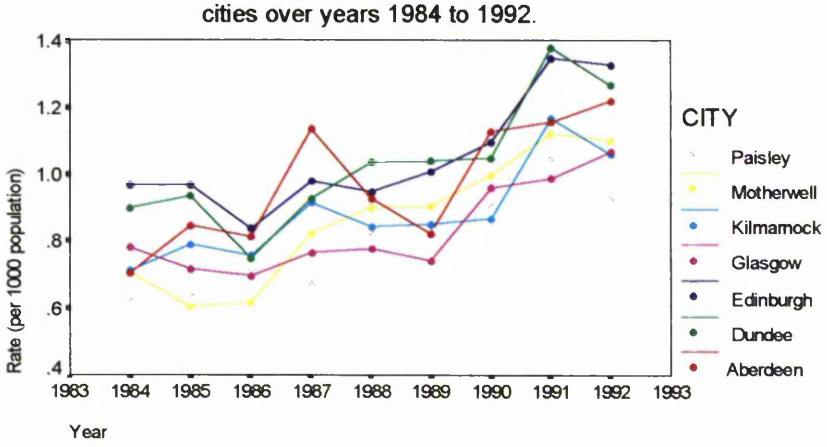
years 1984 to 1992. This plot indicates that in all these cities the rate of first asthma admissions have increased over the years 1984 to 1992. In some these cities such as Dundee, Edinburgh and Motherwell the increase is sharper than others. Hence that the rate of first asthma admission in Aberdeen in year 1987 has increased very sharply.

Table 2-5-3: Numbers and average rates (per 1000 population) of first asthma admissions in different cities of Scotland (1984-1992).

City	Number of first admissions	Rate
Aberdeen	3834	0.98
Dundee	2571	1.03
Edinburgh	7136	1.06
Glasgow	9069	0.83
Kilmarnock	2940	0.89
Motherwell	2914	0.86
Paisley	2649	0.80

* Cities are defined according to post codes.

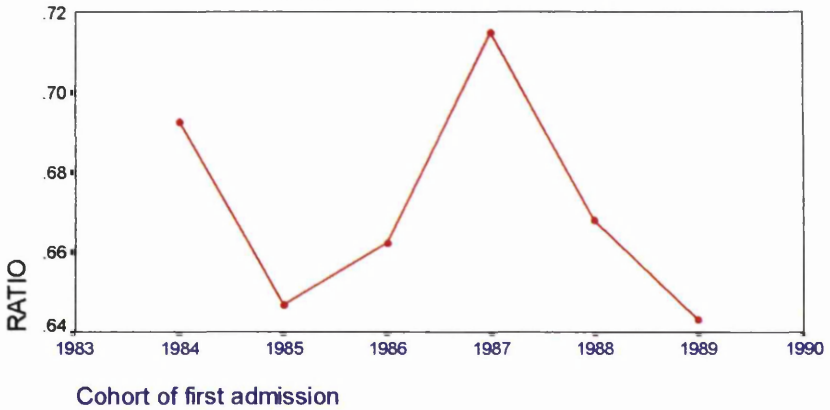
Plot 2-5-4: Rates of first asthma admissions in different cities over years 1984 to 1992.



Plot 2-5-5 shows the ratio of numbers of later asthma admissions in a 3 year horizon after first admission to numbers of first admissions in different cohorts (1984 to 1989) of first admission. We considered the number of later asthma admissions in a 3 year period after first admissions because it was needed to fix the observed time for each asthmatic patient. Note that if two asthmatic patients are observed for different time periods then it is not surprising that the patient who has been observed for longer time has more chance of having more later admissions. Note that since each asthmatic patient should be followed up for full three years, only those asthmatic patients whose first admission has occurred before year 1990 (i.e. up to end of year 1989) could be considered. It implies when we investigate the pattern of later asthma admissions in a 3 year horizon after first admission we can include only the cohorts of first admissions of 1984 to 1989.

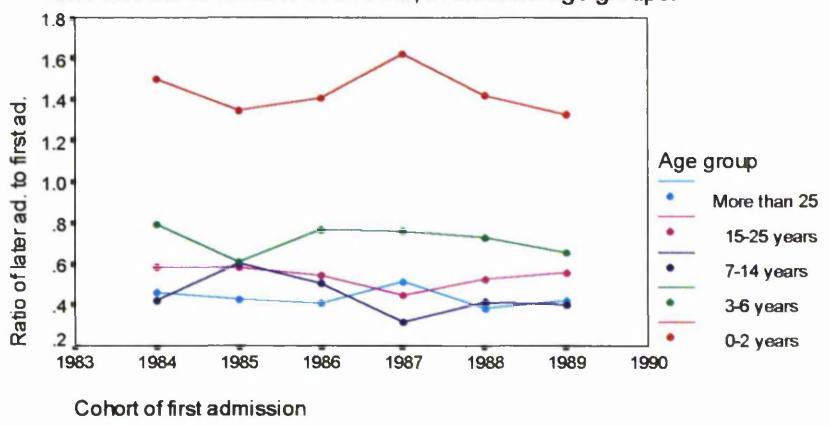
Plot 2-5-5 shows that those asthmatic patients whose first asthma admissions occurred in year 1987 (i.e. cohort of later admissions corresponding to first admission in 1987) have more later admissions in a 3 year horizon after first admissions (with respect to their number of first admission) compared to later admissions of other cohorts. Note the ratio of numbers of later admission (in a 3 year horizon after first admission) to number of first admission corresponding to cohorts 1985 and 1989 are the smallest ones i.e. asthmatic patients corresponding to these two cohorts are less likely to return to hospital than patients in other cohorts. A test in section 2-8 (table 2-8-1) indicates that these differences between these ratios are significant ($P<0.0001$).

Plot 2-5-5: Ratio of first admisions to later admissions in different cohorts of first admission.



Plot 2-5-6 shows the ratio of number of later admissions of asthmatic patients in a 3 year horizon after first admission to number of first admission by cohort of first admission in different age groups. The plot indicates that the ratio of number of later admissions (in a 3 year horizon after first admission) to number of first admissions in different groups does not change very much over the years 1984 to 1989. Table 2-5-4 shows the numbers of baby's later asthma admissions (in a 3 year horizon) and numbers of baby's first admissions in

Plot 2-5-6: Ratio of numbers of later admissions in a 3 year horizon after first ad. to number of first ad., in different age groups.



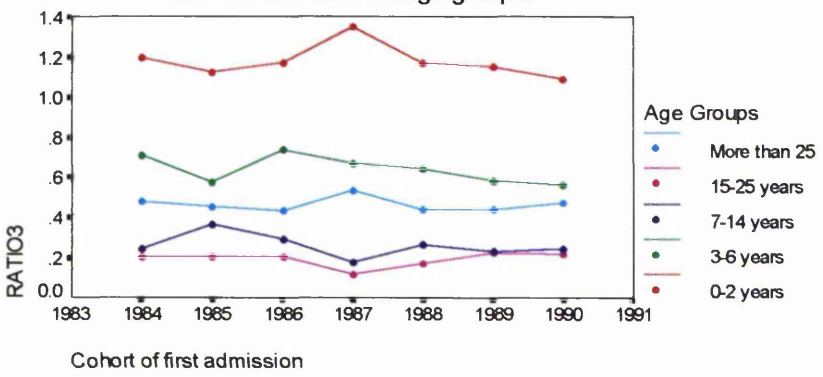
different cohorts of first admission. This table was prepared to investigate whether ratios of baby's later admissions (in a 3 year horizon) to first admissions have significantly changed over years 1984 to 1989 or not. Table 2-5-4 indicates that the changes in the mentioned ratio is significant (P<.0001). Hence the main different ratio is due to cohort 1987. This may explain the large ratio of later to first admissions in year 1987 in plot 2-5-5.

Table 2-5-4: Chi-square test for comparing the baby's numbers of later asthma admissions in a 3 year horizon after first admission with the expected number of later admissions in different cohorts of first admission.

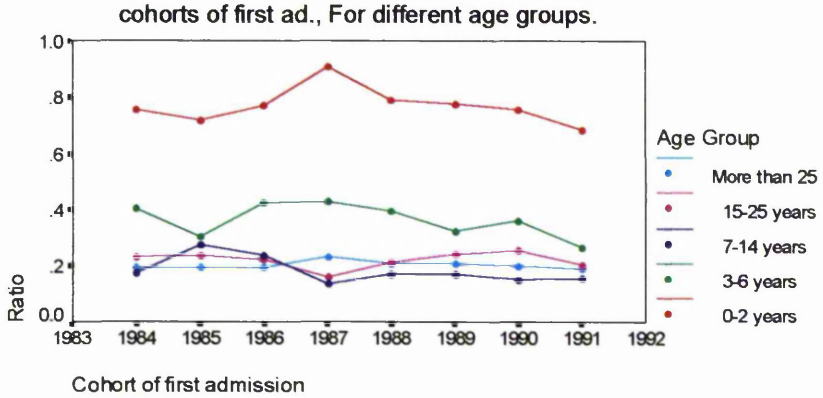
Cohort of first admissions	**No. of First Admissions**	**No. of Later Admissions**	**Expected No. of Later admissions**	$\sum(o_i-e_i)^2/e_i$
1984	604	906	873	1.25
1985	571	773	825	3.28
1986	582	820	841	0.52
1987	813	1321	1175	18.14
1988	824	1172	1191	0.30
1989	760	1012	1099	6.89
	4154	6004	6004	X^2=30.38, df=5, P<.0001

Plots 2-5-7 and 2-5-8 are similar plots to 2-5-6 but they have been prepared to investigate the changes over time in the ratio of number of later asthma admissions, respectively, in a 2 and a 1 year horizon after first admission to number of first admission. These two plots show a similar age profile as plot 2-5-6. Note that when the number of later admissions in a 2 year horizon or in a 1 year horizon after first asthma admission are considered, it is possible to consider those asthmatic patients whose first admission is all years up to, respectively, 1990 and 1991.

Plot 2-5-7: ratio of numbers of later ad. in a 2 year horizon after first ad. to numbers of first ad. in different cohorts of first ad. and different age groups.



Plot 2-5-8: Ratio of numbers of later ad. in 1 year horizon after first ad. to numbers of first ad. in different cohorts of first ad., For different age groups.



2-6 : Fashions in Scotland's cities in diagnosis of the type of asthma disease :

In this section we report on fashions in diagnosing the type of asthma in different cities. By fashion in diagnosis we mean any unscientific tendency which may exist in doctors to label a patient's asthma as acute or chronic. This tendency could be different from one doctor to another one, or from a group of doctors (say working in same hospital or are in touch with each other in some way) to another group. At bigger scale, this tendency could arise in different hospitals or different cities. Unfortunately, since we have too many hospitals and as result, not large enough number of patients in each hospital, it was not possible to investigate whether there is any fashion in diagnosis in any given hospital. However, as some cities had large enough number of new patients, it was possible to carry out this investigation for these.

Table 2-6-1 shows the number of first asthma admissions (from year 1984 to 1992) according to their type of asthma in different cities for babies age group (0-2 years old). Table 2-6-2 to 2-6-5 are similar tables as number 2-6-1 but have been produced for age groups, respectively, 3-6 years old patients, 7-14 years old, 15-25 years old and more than 25 years old. Tables 2-6-4 and 2-6-5 which are due to adults do not illustrate any clear or particular fashion in labelling the asthmatic patients as having acute (code 4930) or chronic (code 4939) asthma but tables 2-6-1 to 2-6-3 indicate the existence of a very strong and consistent fashion in diagnosing types of asthma in some cities for children. Note that all these 3 mentioned tables are due to those asthmatic patients who were less than 15 years old at the time of first admission. The

claim for existence of a fashion in identifying the type of asthma, has come from this fact that in some cities almost all childhood asthma is labelled as acute asthma while in some other cities all are recognised as chronic asthma. The difference between the number of patients with acute or chronic asthma in different cities is too large to believe it is due to differences in type of asthma in different cities. Table 2-6-1 shows that in Aberdeen, Edinburgh and Motherwell, the fashion is to diagnose children's asthma as acute asthma (code 4930) while in Dundee, Glasgow and Kilmarnock they used to label them as chronic asthma (code 4939). In Paisley, the doctors equally label the asthmatic patients as having acute or chronic asthma.

Tables 2-6-1 to 2-6-3 confirm that the type of asthma is definitely not a valid factor to be used in modelling the number of first admissions for children. Hence, even though the tables 2-6-4 and 2-6-5 do not indicate any clear fashion in diagnosis of asthma type for adults, it is difficult to trust the diagnoses of asthma type for these groups of asthmatic patients as well.

Two important consequence follow from this discovery. First, the asthma type which is reported by doctor, is no longer a valid factor to be used in modelling the first (or later) admissions and, if it is used, the main effect of asthma type and particularly the interaction terms involving this factor will not be valid. Hence any effect which refers to asthma type may only be the effect of differences between doctors in diagnosis of asthma type in different cities i.e. this effect is due to cities and not due to asthma type. The second outcome, which was mentioned before, is that there is a very strong fashion in diagnosis the type of asthma which is different in different cities. These fashions in cities could be a sign of the existence of similar fashions in Scotland's hospitals. This factor is therefore dropped from the list of covariates for modelling the pattern of first admissions.

Table 2-6-1 : Frequency of first asthma admissions in different type of asthma and Scotland's cities for asthmatic patients 0-2 years old .

City	First Diagnosis Code 4931		First Diagnosis Code 4930		First Diagnosis Code 4939		Second Diagnosis		Total
	Count.	%row	Count	%row	Count	%row	Count	%row	
Aberdeen	0	0.0	861	90.0	10	1.0	86	9.0	957
Dundee	0	0.0	9	2.0	384	84.8	60	13.2	453
Edinburgh	1	0.1	872	68.8	260	20.5	135	10.6	1268
Glasgow	0	0.0	159	8.9	1551	86.7	79	4.4	1789
Kilmarnock	0	0.0	5	0.9	485	90.7	45	8.4	535
Motherwell	0	0.0	518	81.3	62	9.7	57	8.9	637
Paisley	0	0.0	226	49.0	215	46.6	20	4.3	461

Table 2-6-2 : Frequency of first asthma admissions in different type of asthma and Scotland's cities for asthmatic patients 3-6 years old .

City	First Diagnosis Code 4931		First Diagnosis Code 4930		First Diagnosis Code 4939		Second Diagnosis		Total
	Count.	%row	Count	%row	Count	%row	Count	%row	
Aberdeen	0	0.0	422	90.9	13	2.8	29	6.3	464
Dundee	0	0.0	8	2.2	322	88.5	34	9.3	364
Edinburgh	1	0.1	620	70.5	166	18.9	93	10.6	880
Glasgow	0	0.0	138	11.0	1040	82.5	82	6.5	1260
Kilmarnock	0	0.0	5	1.2	389	92.4	27	6.4	421
Motherwell	0	0.0	396	82.2	52	10.8	34	7.1	482
Paisley	0	0.0	211	45.5	232	50.0	21	4.5	464

Table 2-6-3 : Frequency of first asthma admissions in different type of asthma and Scotland's cities for asthmatic patients 7-14 years old .

City	First Diagnosis Code 4931		First Diagnosis Code 4930		First Diagnosis Code 4939		Second Diagnosis		Total
	Count.	%row	Count	%row	Count	%row	Count	%row	
Aberdeen	0	0.0	377	73.1	56	10.9	83	16.1	516
Dundee	0	0.0	2	0.6	276	84.9	47	14.5	325
Edinburgh	0	0.0	480	57.9	242	29.2	107	12.9	829
Glasgow	0	0.0	119	10.5	900	79.2	118	10.4	1137
Kilmarnock	0	0.0	9	2.2	384	92.1	24	5.8	417
Motherwell	0	0.0	372	75.5	78	15.8	43	8.7	493
Paisley	0	0.0	142	36.1	221	56.2	30	7.6	393

Table 2-6-4 : Frequency of first asthma admissions in different type of asthma and Scotland's cities for asthmatic patients 15-25 years old .

City	First Diagnosis Code 4931		First Diagnosis Code 4930		First Diagnosis Code 4939		Second Diagnosis		Total
	Count.	%row	Count	%row	Count	%row	Count	%row	
Aberdeen	10	1.3	62	8.0	613	79.1	90	11.6	775
Dundee	2	0.3	3	0.5	513	84.0	93	15.2	611
Edinburgh	15	0.9	62	3.7	1252	74.9	342	20.5	1671
Glasgow	20	1.0	24	1.2	1705	84.7	264	13.1	2013
Kilmarnock	4	0.7	6	1.1	485	89.0	50	9.2	545
Motherwell	0	0.0	10	1.7	518	88.9	55	9.4	583
Paisley	11	2.0	59	10.5	433	77.3	57	10.2	560

Table 2-6-5 : Frequency of first asthma admissions in different type of asthma and Scotland's cities for asthmatic patients more than 25 years old .

City	First Diagnosis Code 4931		First Diagnosis Code 4930		First Diagnosis Code 4939		Second Diagnosis		Total
	Count.	%row	Count	%row	Count	%row	Count	%row	
Aberdeen	118	10.5	22	2.0	677	60.3	305	27.2	1122
Dundee	15	1.8	1	0.1	605	74.0	197	24.1	818
Edinburgh	182	7.3	30	1.2	1526	61.3	750	30.1	2488
Glasgow	238	8.3	18	0.6	1881	65.5	733	25.5	2870
Kilmarnock	54	5.3	2	0.2	706	69.1	260	25.4	1022
Motherwell	9	1.3	4	0.6	585	81.4	121	16.8	719
Paisley	33	4.3	13	1.7	565	73.3	160	20.8	771

2-7 : Initial analyses of intensity of patients' later asthma admissions :

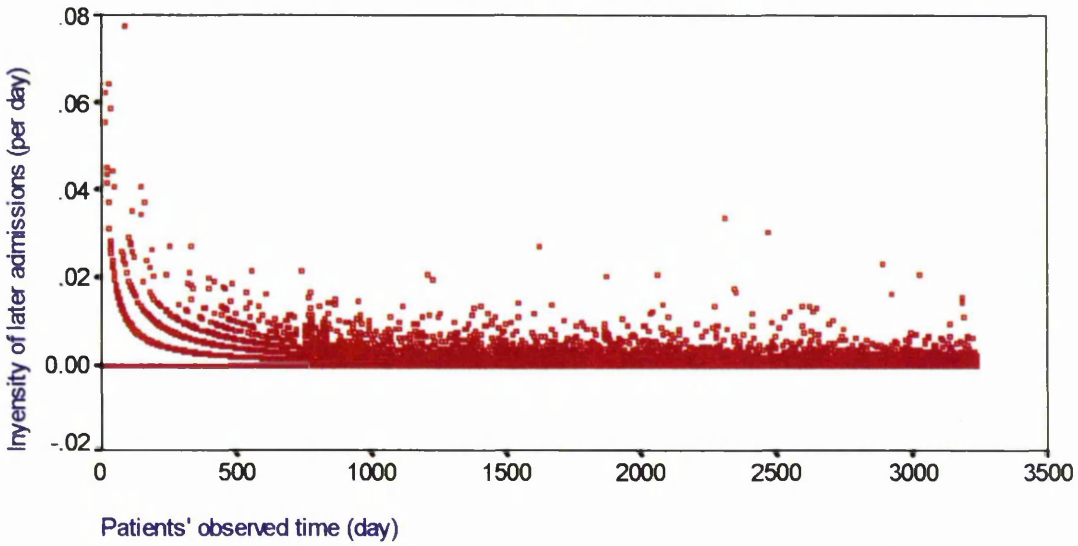
In this section we are going to calculate a new variable for each patient. This new response variable is defined as "the patient's number of later admissions divided by his/her observed time period". The observed time period of each asthmatic patient is defined as the time interval between the patient's date of first discharge from hospital and either the end date of follow up (31st December 1992) or his/her date of death. The observed time periods are calculated in days. This new variable therefore defines the average intensity or hazard of being admitted (over the observed time) for each asthmatic patient. The number of later asthma admissions, which is mentioned in this section, is the number of later asthma admissions of the asthmatic patient over the whole period of observation i.e. we are not considering those number of later asthma admissions of the asthmatic patient which have happened, for example, in his/her first 3 years of first admission. Thus, in this section, the horizon of counting an asthmatic patient's later asthma admissions is not restricted to some part of his/her observed time.

By calculating these intensities it is possible to discuss the likelihood of having an admission for each asthmatic patient and so to find some groups of the patients with some special characteristics who have more or less intensity of later admissions after their first admission. Note carefully that each patient's intensity of later admissions may depend on characteristics of the patient (and maybe some environmental factors such as weather, city and hospital) and it should not depend on the date of first admission. If these intensities depend on

the patients' date(year) of first admission then we should carry out separate analysis for the patients who are grouped according to similar date of first admission. In this case, it is not possible to generalise the result of the study to future admissions. Therefore we should try to define each patient's intensity of admission in some way which does not depend on the date (year) of the first admission.

Note that it is possible to consider each patient's intensity of admission as a response variable for the patient and to try to explain "between patients' variation in having an admission" by this response variable. The important point is that these intensities should be defined in such a way that does not depend on the date(year) of the first admission, otherwise it is not possible to generalise the results to future years.

Plot 2-7-1 : Scatter plot of intensity of later admissions (per day) against the patients' observed time.



To carry out the above ideas, the intensity of later asthma admissions for each of 40,496 patients was estimated by dividing, simply, each patient's number of later asthma admissions by his/her observed time. For investigating

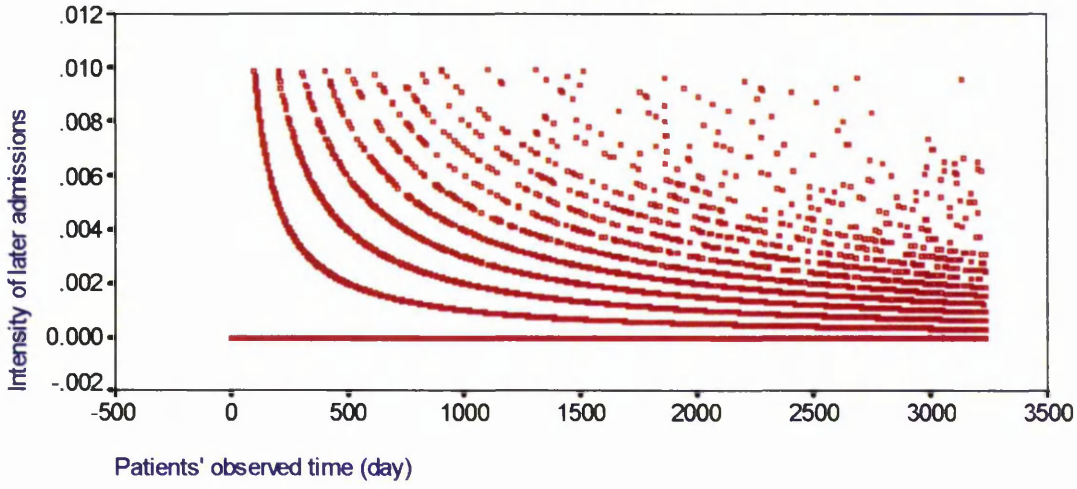
whether the patients' intensity of admission depends on their date of first asthma admission or not, the plot 2-7-1 was produced.

Plot 2-7-1 shows the relation between the estimated intensity of later asthma admissions and the patients' observed time. Here the date of first asthma admission was calculated in days (taking 31/12/1900 as the origin) to be able to consider both the intensity of admission and the date of first admission as continuous variables. Several separate curves exist in this plot, one for each number of later asthma admission. Between these curves, those which are due to those patients who had 0, 1, 2, 3, 4, 5 and even 6 later asthma admissions are quite clear. Hence the reason that the curves due to the patients with other number of later asthma admissions are not clearly seen is that there are a few number of patients with more than 6 later asthma admissions and also it is very unlikely to have more than 6 later asthma admissions for those patients who have been observed for a short time. Plot 2-7-1 indicates that, for those asthmatic patients who were observed for a short time, their intensity of later asthma admissions is extremely variable. It shows that for this group of asthmatic patients the maximum intensity of admission decreases sharply as the observed time increases. From plot 2-7-1 it is difficult to make any statement about the relation between the patients' observed time and their intensity of later asthma admissions for those patients who were observed for a relatively long time. Plot 2-7-2 is a similar plot to 2-7-1 but has been prepared only for those asthmatic patients whose intensities of later admissions are less than 0.01. This plot makes it possible to investigate the relation between the patients' intensities and their observed time for those asthmatic patients who have been observed for a relatively long time. This new plot also suggests that the intensity of later asthma admissions of this group of asthmatic patients is related to their observed times. Hence both plots 2-7-1 and 2-7-2 may indicate

that the estimated intensities depend on the patients' observed time period and as it increases the intensity of later asthma admissions decreases.

Plot 2-7-2 : Plot of intensity of later admissions (per day) against the patients' observed time.

The large values of intensities are deleted.



We have already shown that an asthmatic patient's intensity of later asthma admission depends on his/her observed time period and as the patients' observed times periods increase, the intensity of later asthma admissions decreases. Here we try to illustrate the changes in mean of intensity of having a later asthma admission for asthmatic patients in different age groups or different cohorts of first asthma admission.

To discuss the changes in intensity or to obtain some ideas about the pattern of intensity of later asthma admissions, it was decided to consider the asthmatic patients who are in a particular age group and particular cohort of first asthma admission, as a group. In each of these groups of asthmatic patients, the mean of intensity of having a later asthma admission in each year after first asthma admission, up to fifth year, was estimated by dividing their total number of later asthma admissions in that particular year by the number of

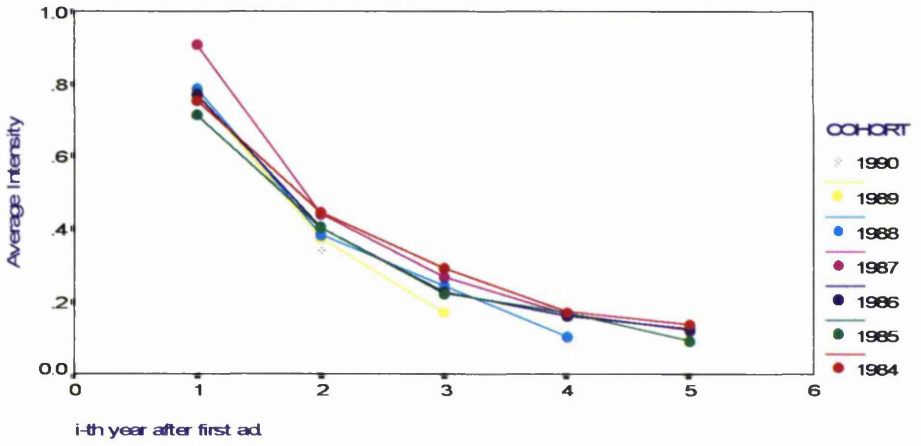
asthmatic patients in the group. Note that since 9 cohorts of asthmatic patients exist and in each cohort 5 age groups are considered and in each particular age group and cohort, the mean of intensity is estimated for first to fifth year after first asthma admissions, therefore $9\times5\times5=225$ means of intensities are estimated. However since some asthmatic patients were not followed up for at least full 5 years, some of these means could not be estimated. Some of these means, which were possible to be estimated but did not belong to a full year follow up, were also excluded from the analyses. Note that excluding of these means is needed because if any of the estimated means is not due to a full year of follow up then it is not comparable with the other means of intensity. These means of intensity were used to illustrate the pattern of mean of intensity of later asthma admissions in different age groups, different cohorts and in different years after first asthma admission.

Plots 2-7-3 to 2-7-7 show the mean of intensity of later asthma admissions in different years after first asthma admissions for different cohorts of first asthma admissions and in different age groups. Each of these plots represents a particular age group. Age groups are constructed according to age of asthmatic patients at time of first admission. Overall, these plots suggest that, in different age groups, the mean of intensity of returning to hospital decreases as the year from the first admission increases. The pattern of changes in mean of intensity of returning to hospital for the asthmatic patients who were 0-2 years or 3-6 years old (at time of first admission) is more similar than the other age groups. The sharpest decrease in mean of intensity of returning to hospital is always due to first year to second year after first asthma admission. There is one exception in decrease of mean of intensity in years later than second year and it is due to cohort 1987 in age groups 7-14 and 15-25 years. In this cohort, the mean of intensity of returning to hospital, in two mentioned age groups, has

not decreased after the second year of first asthma admission. Also, for the 15-25 year group, cohort 1987 showed lower mean intensities than other cohorts.

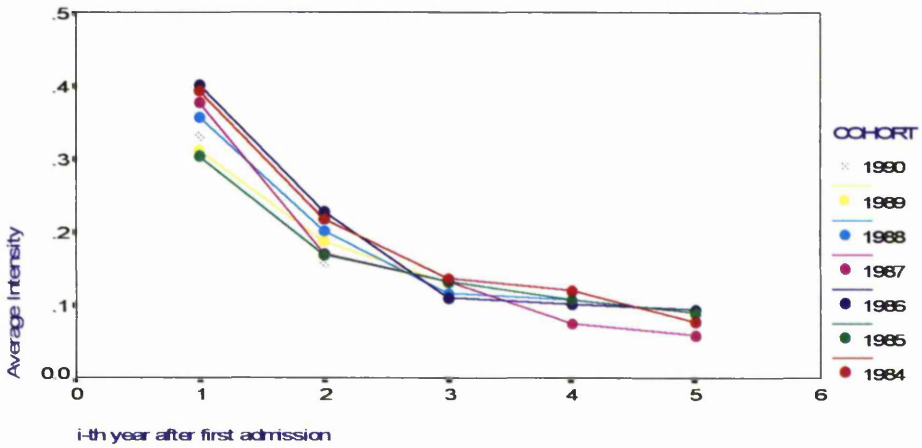
Plot 2-7-3 : Average intensity of admission in different years after first admission. For different cohort of first admission.

For 0-2 years old



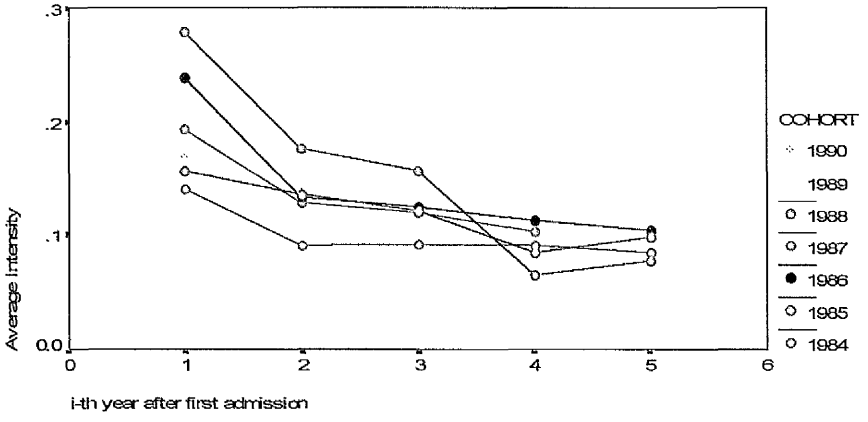
Plot 2-7-4 : Average intensity of admissions in different years after first admission. For different cohort of first admission.

For 3-6 years old



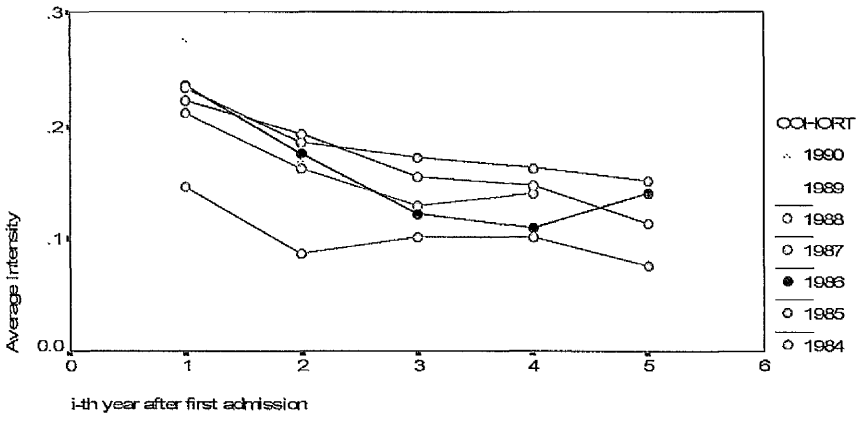
Plot 2-7-5 : Average intensity of admission in different years after first admission. For different cohort of first admission.

For 7-14 years old



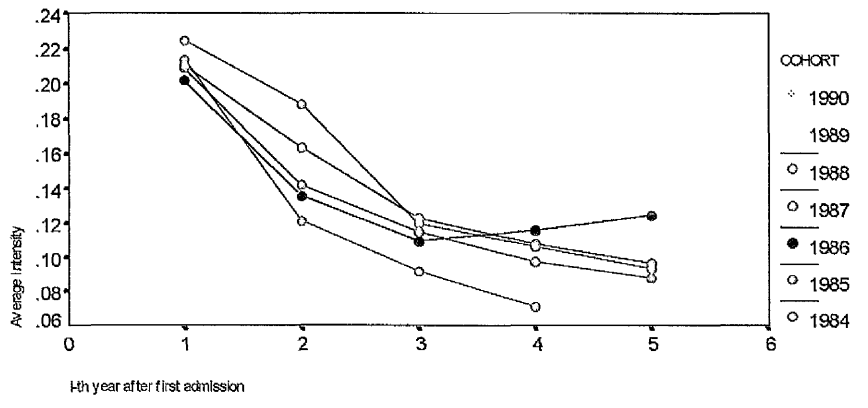
Plot 2-7-6 : Average intensity of admission in different years after first admission. For different cohort of first admission.

For 15-25 years old



Plot 2-7-7 : Average intensity of admission in different years after first admission. For different cohort of first admission.

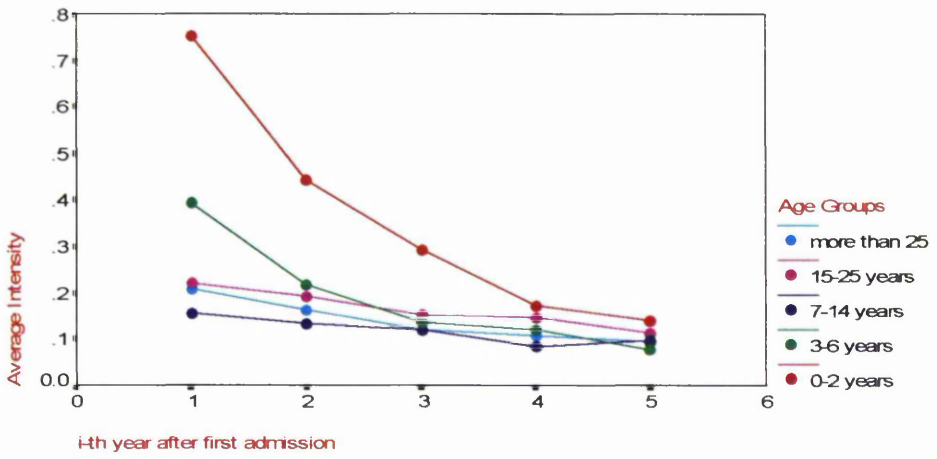
For more than 25 years old.



Plots 2-7-8 to 2-7-14 were again prepared to investigate the changes in mean of intensity of later asthma admissions in different years after first admission for different age groups and different cohorts. However now these plots (in contrast to the plots 2-7-3 to 2-7-7) show the age profiles for a particular cohort of first admission. These plots suggest that the changes in mean of intensity of returning to hospital in different years after first admission, for all age groups, is very similar in different cohorts. It implies that year of first asthma admission has little if any effect on the intensity of later asthma admissions (i.e. on number of later asthma admissions).

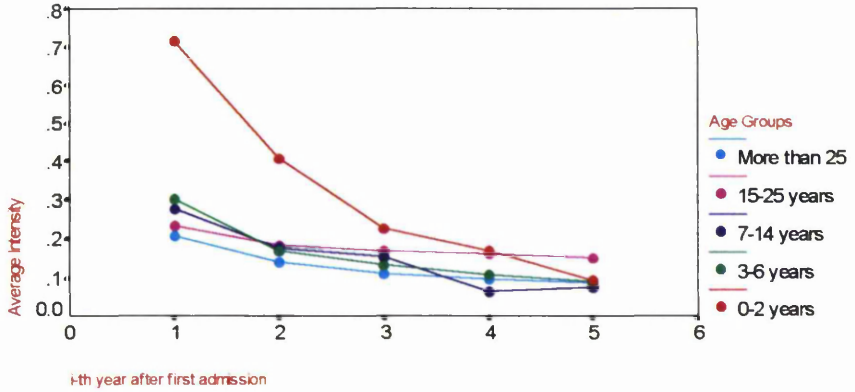
Note particularly that, in the early years after first admission, the mean intensity for patients 0-2 years old, at first admission greatly exceeds that for 3-6 years olds. This in turn usually exceeds the mean intensities for older age groups. However, by the fifth (or even the fourth) year after first admission, the mean intensities have declined to rather similar values for all age groups.

Plot 2-7-8 : Average intensity of later admissions in different years after first admission. For different age group. For cohort of first admission 1984.



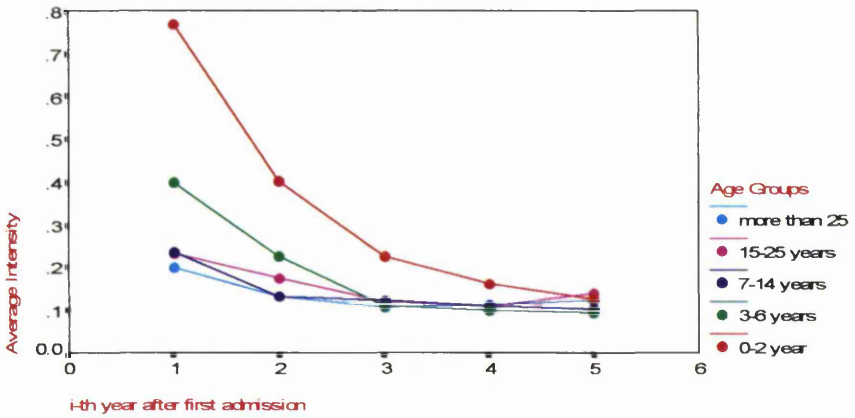
Plot 2-7-9 : Average intensity of later admissions in different years after first admission. For different age group.

For cohort of first admission 1985.



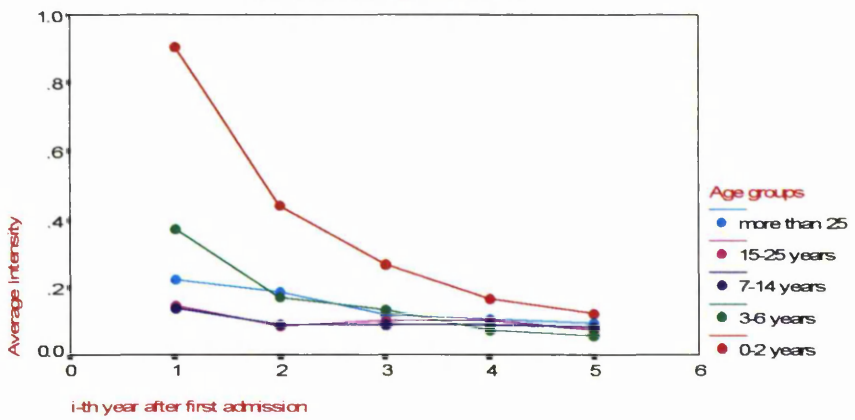
Plot 2-7-10 : Average intensity of later admissions in different years after first admission. For different age groups.

For cohort of first admission 1986.



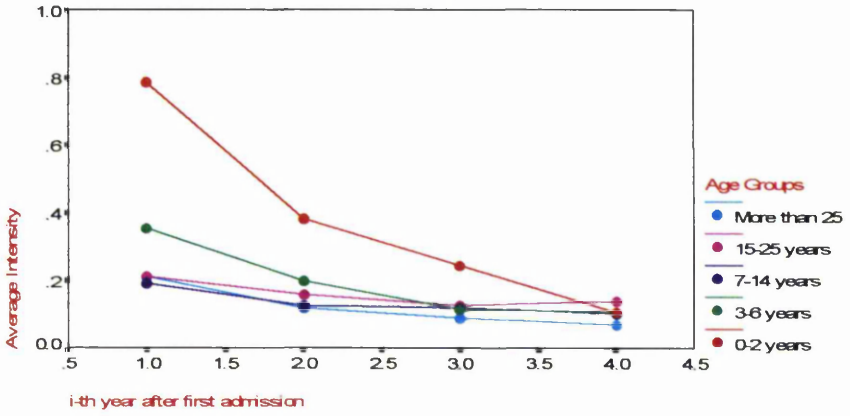
Plot 2-7-11 : Average intensity of later admissions in different years after first admission. For different age group.

For cohort of first admission 1987.



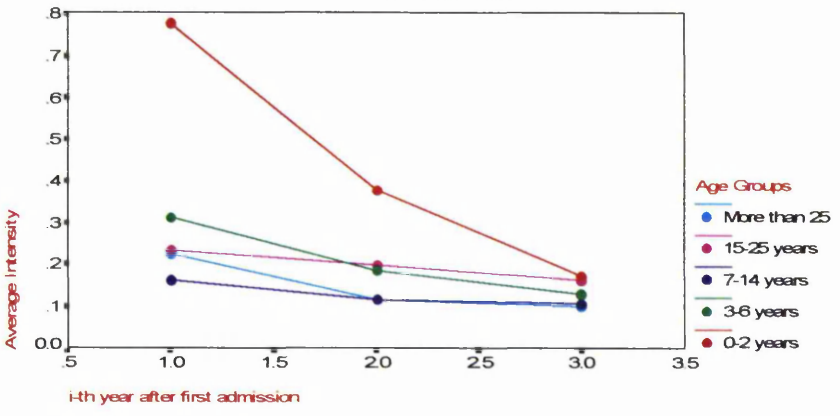
Plot 2-7-12 : Average intensity of later admissions in different years after first admission. For different age groups.

For cohort of first admission 1988.



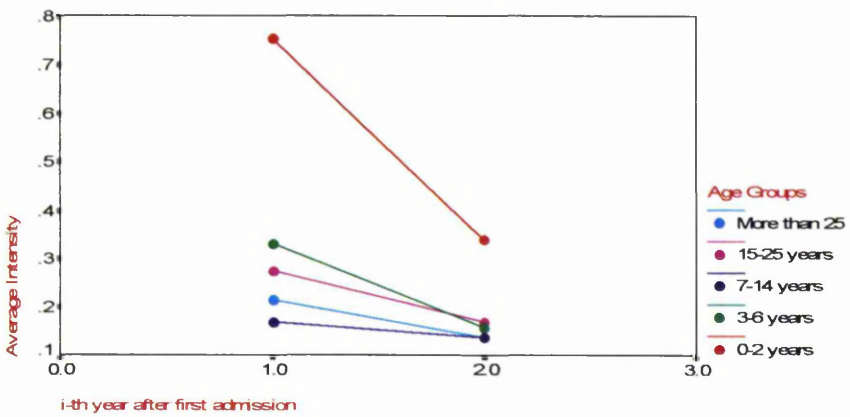
Plot 2-7-13 : Average intensity of later admissions in different years after first admission. For different age groups.

For cohort of first admission 1989.



Plot 2-7-14 : Average intensity of later admissions in different years after first admission. For different age group.

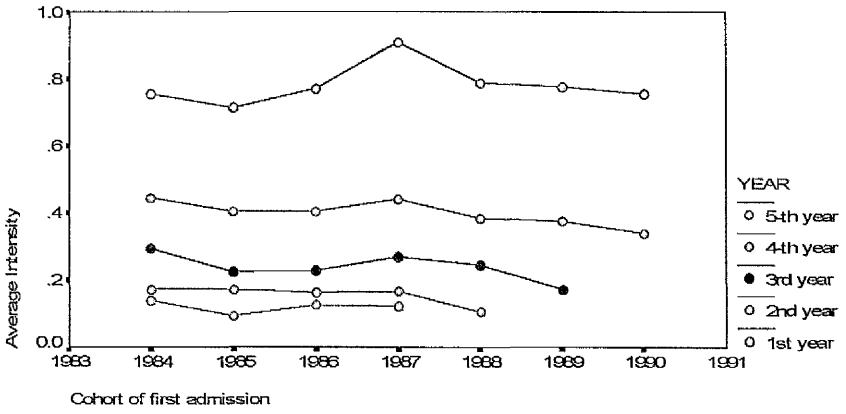
For cohort of first admission 1990.



Plots 2-7-15 to 2-7-19 show the changes in mean of intensity of returning to hospital in first, second, third, fourth and fifth year after first admission in different age groups and different cohorts of first admission. Each of these plots stands for the mentioned pattern in a particular age group. These plots suggest that the mean intensity of later asthma admissions decreases as the patients' observed time increases. The mean of intensity of later asthma admissions at first year after first asthma admission, in all cohorts and all age groups, is considerably higher than the mean of intensity in other years. The intensity of returning to hospital does not change very much from third to fourth and from fourth to fifth year after first asthma admission. Most of plots 2-7-15 to 2-7-19 suggest that something special has happened in cohort 1987. It is the cohort of asthmatic patients whose first asthma admissions have happened in year 1987. In this cohort, the mean of intensity of returning to hospital in some years after first asthma admission and in some age groups is more or less than the mean of intensity in other years or other age groups. Plot 2-7-15 indicates that the mean of intensity of returning to hospital in first year after first asthma admission between patients who are 0-2 year old in cohort 1987, is higher than the mean of intensity in same age group and same year after first asthma admission in other cohorts. It is the case in second year after first asthma admission for the patients who are more than 25 years old. On the other hand, plots 2-7-16 and 2-7-18 suggest there is a trough in mean of intensity of returning to hospital, respectively, due to age groups 3-6 years and 15-25 years in all years after first asthma admission (i.e. in first up to fifth year after first asthma admission) in cohort 1987.

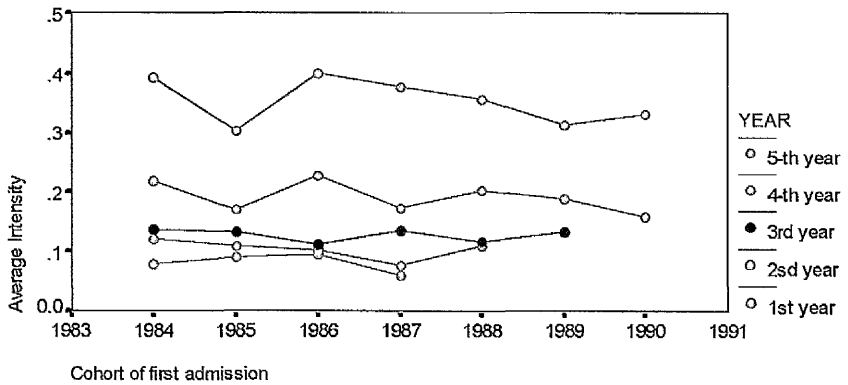
Plot 2-7-15 : Average intensity of later admissions in different cohort of first admission. For different years after first admission.

For 0-2 years old.



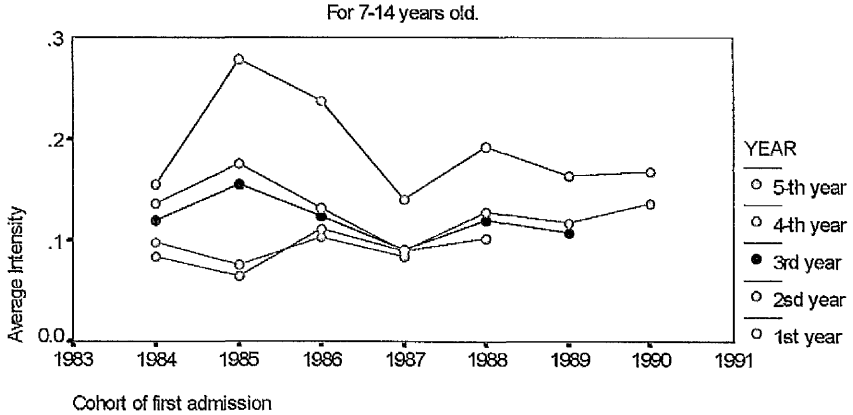
Plot 2-7-16 : Average intensity of later admissions in different cohort of first admission. For different years after first admission.

For 3-6 years old.



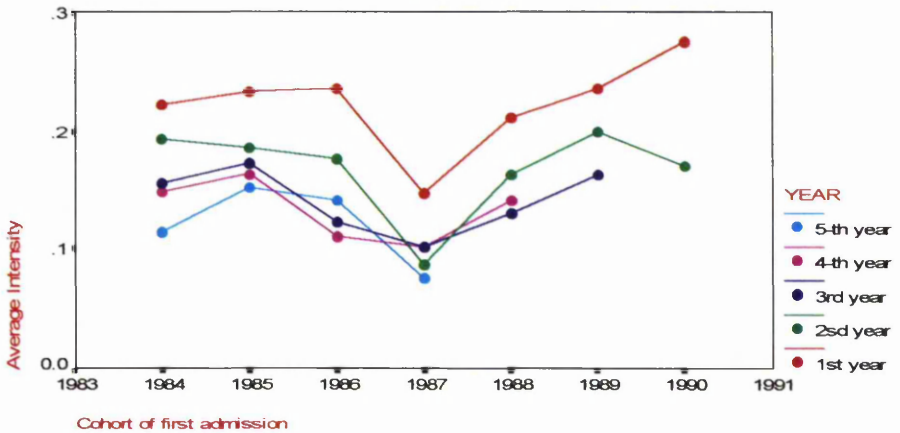
Plot 2-7-17 : Average intensity of later admissions in different cohort of first admission. For different years after first admission.

For 7-14 years old.



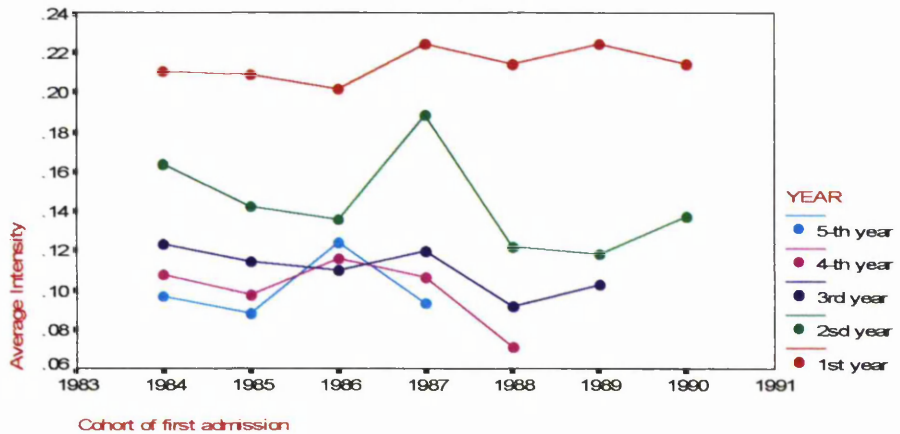
Plot 2-7-18 : Average intensity of later admissions in different cohort of first admission. For different years after first admission.

For 15-25 years old.



Plot 2-7-19 : Average intensity of later admissions in different cohort of first admission. For different years after first admission.

For more than 25 years old.

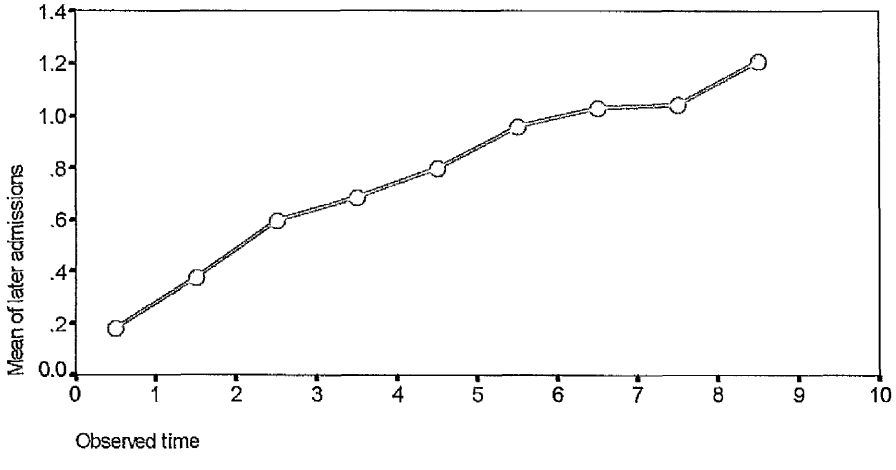


As discussed above, plots 2-7-3 to 2-7-14 show how the average intensity of later asthma admissions declines as time passes after first asthma admission.

The different cohorts (1984 to 1992) of asthma patients have been observed for very different periods of time since first asthma admission. Therefore the mean number of later asthma admissions, over the whole of each patient's observed time, will not be simply proportional to that observed time. This conclusion is illustrated in plot 2-7-20.

Plot 2-7-20 is the scatter plot of the "mean of number of later asthma admissions in each cohort of first asthma admission" against the "mean of the patients' observed time". Note that the patients who are due to cohorts of first asthma admissions of 1984 to 1992, have been observed on average, respectively, 8.5, 7.5, 6.5, 5.5, 4.5, 3.5, 2.5, 1.5 and 0.5 years. In each cohort, mean of number of later asthma admissions has been calculated by dividing the total number of later asthma admissions in the cohort by number of asthmatic patients in the cohort (i.e. number of first asthma admissions). Plot 2-7-20 shows that after 3 years after the date of first admission, mean of number of later asthma admissions does not increase as sharply as it increases in first 3 years after date of first asthma admission. This plot indicates that there is not much difference between mean of later asthma admissions of those patients who were followed up for 6 years with mean of those who were followed up for 7 years.

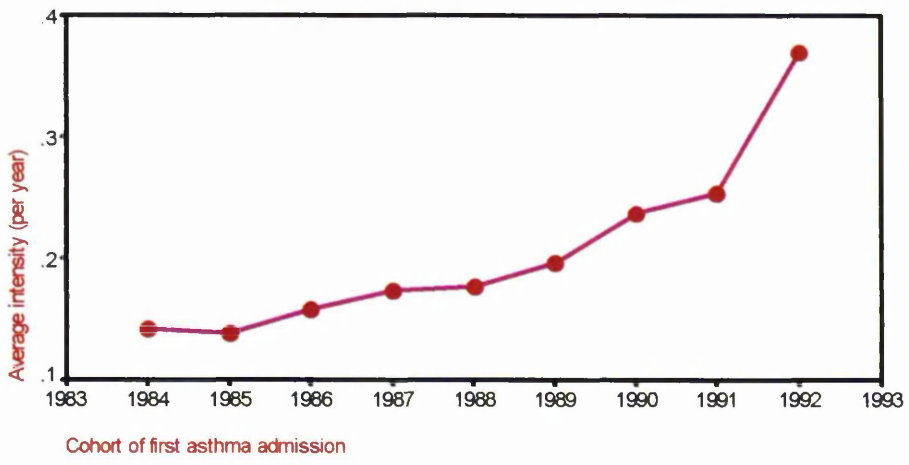
Plot 2-7-20 : Relation between the mean of number of later asthma admissions and the observed time.



Previously it was discussed that the number of later asthma admissions is not simply proportional to time since first asthma admission and it was shown that the intensity of returning to hospital declines sharply as time passes

after first asthma admission. It implies the asthmatic patients due to those cohorts which have been followed up for shorter time since first asthma admission, should have greater mean of intensity of returning to hospital per year in comparing with the patients who are due to other cohorts; for instance the 1992 cohort is observed for between 0 and 12 months after first asthma admission, and can be expected to have the greatest average intensity (per year) of later asthma admissions. The reason is that all asthmatic patients of this cohort are in their first year after first asthma admission and should be expected to have the greatest intensity of returning to hospital. This conclusion is illustrated in plot 2-7-21. This plot shows the mean of intensity of later asthma admissions per year for different cohorts of first asthma admissions. The mean of intensity of later asthma admissions in each cohort is calculated by dividing the mean of number of later asthma admissions in the cohort by average number of years which cohort has been followed up. The mean of number of later asthma admissions in each cohort, as was explained before, is calculated by dividing the number of later asthma admissions in the cohort by number of asthmatic patients in the cohort. The averages numbers of follow up for cohorts

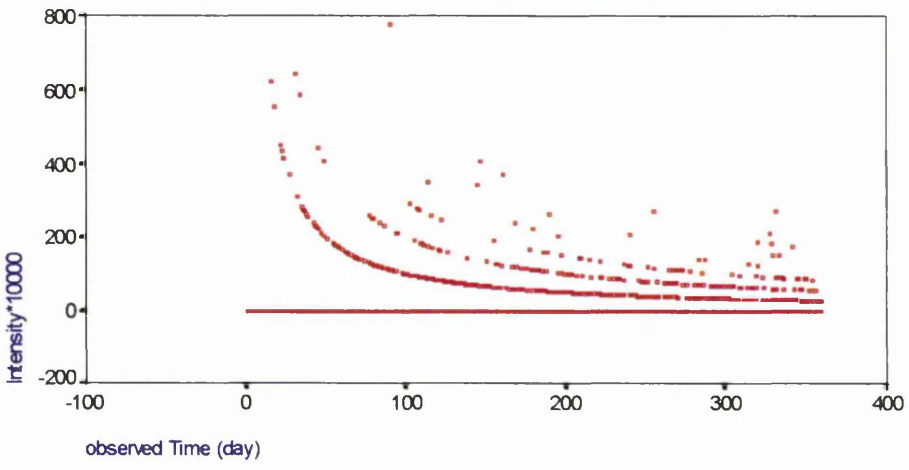
Plot 2-7-21 : Average intensity of later asthma admissions per year in different cohorts of first asthma admissions.



1984 to 1992 are, respectively, 8.5, 7.5, 6.5, 5.5, 4.5, 3.5, 2.5, 1.5 and .5 years. Plot 2-7-21 indicates that the mean of intensity of returning to hospital (per year) for cohort 1992 is very different from other cohorts.

To investigate how reliable the mean of intensity of later asthma admissions per year in cohort 1992 is, plot 2-7-22 was prepared. This plot shows the intensity of later asthma admissions for individual patients of cohort 1992 plotted against their time of follow up in days. Curves corresponding to exactly one, two, three, ... later asthma admissions can be seen. Note that those patients who were followed up for very short times, can have very large intensity. It is possible that the variance of the intensity approaches to infinity as the days in study approaches to zero. In practice it means those values of the intensity which are due to small number of days in the study are unreliable. Hence the small number of days in study only may happen for those patients whose date of first admission occurred in the year 1992. Later we will mention that only later admissions in a 3 year horizon after first admission will be considered to investigate the between patients variation in later asthma

Plot 2-7-22 : Plot of patients' intensity (per day) of later asthma admissions for cohort 1992 against their observed time.



admissions. In this case, a reason for ignoring the patients whose first asthma admission occurred in the year 1992 is that the estimated intensities of these patients are not reliable.

To compare cohorts simply we decided now to impose a horizon of 3 years after first asthma admissions.

The table 2-7-1 shows the mean of later asthma admissions and the mean of the intensity of later asthma admission (per year) in two different horizons in different cohorts. The first horizon is as the end of study (i.e. 31/12/1992) and the second horizon is within 3 years after the date of first asthma admission. Note that, when a 3 year horizon is considered, the asthmatic patients due to cohorts 1984 to 1989 have been observed for full

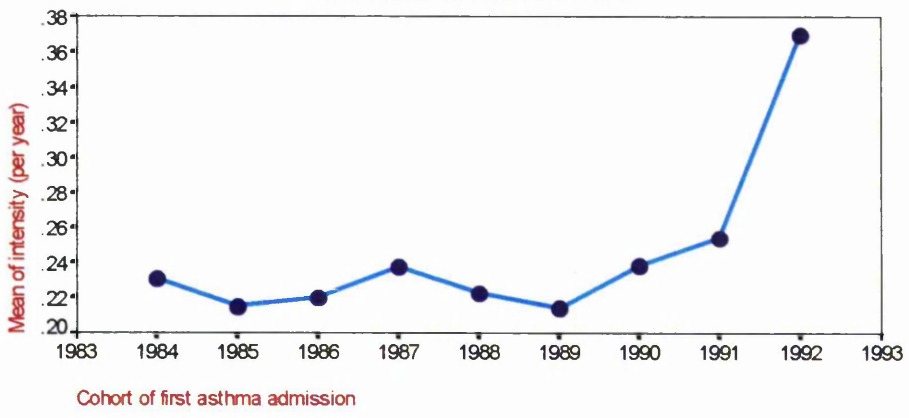
Table 2-7-1: Mean of number of later asthma admissions and mean of intensity of later asthma admission in a horizon as the end of study and in a 3 year horizon after first admissions in different cohorts of first admission.

Cohort of First Admissions	Mean of Later Admissions	Mean of Intensity of Later Admissions per year	Mean of Later Admissions within a 3 year horizon	Mean of Intensity of Later Admissions within a 3 year horizon
1984	1.210	0.14235	0.6927	0.2309
1985	1.040	0.13867	0.6470	0.2157
1986	1.029	0.15831	0.6624	0.2208
1987	0.956	0.17382	0.7150	0.2383
1988	0.800	0.17778	0.6681	0.2227
1989	0.689	0.19686	0.6435	0.2145
1990	0.596	0.23840	0.5963	0.2384
1991	0.382	0.25467	0.3821	0.2547
1992	0.185	0.37000	0.1853	0.3700

three years after first asthma admissions while those patients who are due to cohorts 1990, 1991 and 1992 have been followed up for less than 3 years. Here the mean of later asthma admissions and the mean of intensity of later asthma admissions have been calculated in same manner as before.

Plot 2-7-23 shows the mean of intensity of later asthma admissions in a within 3 years horizon after first admission. From this plot one can see the mean of intensity of admission (within 3 years after first admission) of those asthmatic patients who were admitted in the year 1992 (cohort 1992) is much greater than the mean of intensity of admission of those whose first asthma admission had been in other years. Even though the one way analysis of variance test applied to individual patients indicated the mean of the intensity of later asthma admissions (within 3 years after first admission) in different cohorts are also significantly different but one can see (from the plot 2-7-23) that these means, except the one due to cohort 1992, are close to each other. Remember that we are dealing with a very large data set therefore every small differences can be significant without being important.

Plot 2-7-23 : Plot of mean of intensity of later asthma admissions (per year) in a within 3 years horizon after first asthma admissions in different cohorts.



In previous paragraphs it was shown that the intensity of later asthma admissions of an asthmatic patient declines as the patient passes through the years after his first asthma admission e.g. the mean of intensity of later asthma admissions decreases sharply from first year to second year since first asthma admission. Here we claim (and we will give some reasons) that not only an asthmatic patient's intensity of later admissions decreases from each year to next year after first asthma admission but also it varies within each year after first asthma admissions. One reason is that there could be a lack of uniformity in time (in each year) for occurrence of later admissions. One source of this non-uniformity can be the existence of seasonal pattern. If there is any seasonal pattern, the intensity of later asthma admission in some months of year is greater than the other months. This means not only that the intensity function of each patient is not a constant function over his/her observed time but also that his/her expected number of later asthma admissions depends on which months of the year the patient has been at risk of admission. Since we suppose that each event of admission is independent of the previous event we now consider a non-homogenous Poisson process model for pattern of later asthma admissions.

We remind the reader that we previously reported the existence of seasonal pattern in occurrence of asthma admissions in section 2-4. This implies that a non-uniformity in occurrence of later asthma admissions exists resulting in the asthmatic patients not having a constant intensity of having a later asthma admission over a single year. Thus not having a constant intensity function for occurrence of later asthma admissions, will lead us to this very fundamental question of which covariates or factors this intensity function depends on. In chapter 4 and elsewhere some formal models will be used to

investigate the relation between the intensity of having a later asthma admission and the characteristics of the asthmatic patients.

2-8 : Initial analyses of later asthma admissions : (Between patient variations and relations with explanatory variables)

In this section we intend to find the factors which are significantly related to the number of patients' asthma admissions. We are also interested in discovering the factors which have significant effect on the seasonal pattern of asthma admissions. Remember that it was shown in section 2-4 that there exists a seasonal pattern in asthma admissions which is different in different age groups. The seasonal patterns suggested that individuals are at more risk of being admitted in some months (September, October, November and sometimes December) compared to the other months of the year. Before going through the analyses and as a reminder we should say the data set we are working with contains episodes of asthma attack which caused the asthmatic patient to be admitted to a hospital. More precisely, the data set does not contain those asthma attacks of any asthmatic patient which was not serious enough to result in hospitalisation.

In addition to the explanation which was added at the end of the previous paragraph we should add that, for making sure that the differences in the number of admissions of the asthmatic patients is not due to the time interval that the patients were observed, it was decided to fix the observed time for all asthmatic patients. We decided to choose only those admissions of an asthmatic patient which occurred over an exactly 3 year follow up period. The idea of choosing 3 years as the identical observed time for all asthmatic patients came from this main implication that if we choose some years more than 3

years as the horizon then to follow up the patients for full those number of years we should select only those patients who are possible to be followed up for those number of years e.g. to consider the number of later asthma admissions of an asthmatic patient in a 5 year horizon after his/her first admissions it requires that the patient would been admitted at latest in year 1987 (because the follow up is ended in 1992). Note that a longer horizon causes to have a smaller number of years in analysing the trend of later admissions over years. Hence we should compromise in choosing the horizon.

Since the end day of study is 31st of December 1992, therefore some patients whose first admission occurred later than the year 1989, can not be observed for full 3 years. These patients were deleted from this part of study. As the result, the data set which we are going to use, contains all admissions of all asthmatic patients whose date of first admission was in years 1984 to 1989 and were followed up exactly for 3 years. If we consider those patients whose first admissions occurred in the same year as a group of patients then we have 9 groups of asthmatic patients (one for each year 1984 to 1992) and we may name these groups "cohort 1984" to "cohort 1992". In this sense, the data set which we are going to use for analyses contains only later admissions which have occurred within 3 years of first admission of each of the cohorts 1984 to 1989.

In this chapter, investigation of the relation between each covariate and either first or later asthma admissions will be presented in two parts. First the effect of some covariates such as age group, sex, marital status, type of diagnosis, type of admissions and city on both first and later asthma admissions will be investigated and then we will investigate the effect of the covariates on the seasonal pattern of the later admissions.

At the start it was decided to test whether the number of later admissions (admissions after first admissions) due to different cohorts (cohorts 1984 to 1989) are or are not statistically different. In a 3 year horizon after first admission, are the numbers of later asthma admissions in each cohort roughly proportional to the number of patients in the cohort? Table 2-8-1 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later asthma admissions in different cohorts of first admission (i.e. cohorts 1984 to 1989). Note that in each cohort the later admissions of asthmatic patients in a 3 year horizon have been considered. The expected number of later admissions in each cohort has been estimated by multiplying "the proportion of first asthma admissions in that cohort to total number of first asthma admissions" by the total number of later admissions.

Table 2-8-1 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different cohorts of first admission.

Cohort of first admissions	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
1984	3876	2685	2603.8	2.53
1985	3952	2557	2654.85	3.61
1986	3741	2478	2513.11	0.49
1987	4362	3119	2930.28	12.15
1988	4329	2892	2908.11	0.09
1989	4275	2751	2871	5.08
Total	24535	16482	16482	χ^2=23.96 d.f.=5

Table 2-8-1 indicates that the number of later asthma admissions in some cohorts of first admission is significantly more or less than the expected

number of later admissions. The difference between the number of later asthma admissions and its expected values in the cohort 1987, is the highest. This suggests that the asthmatic patients in some cohorts (especially cohort 1987) are at more risk of returning to hospital than the patients in some other cohorts. Thus the effect of the covariates should be investigated separately for each cohort of first admission or in any proposed model the year of first asthma admission should be included in the model.

Table 2-8-2 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different age groups.

Age Groups	No. of First Admissions (1984-89)	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
0-2 year	4154	6004	2790.55	3700.43
3-6 years	3321	2417	2230.96	15.51
7-14 years	3331	1471	2237.68	262.68
15-25 yeas	5241	2860	3520.77	124.01
more than 25	8488	3730	5702.03	682.02
Total	24535	16482	16482	χ^2=4784.65 d.f.=4

As the first covariate, the effect of age was investigated. Table 2-8-2 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later admissions in different age groups. As before the 5 age groups are, 0-2 year, 3-6 years, 7-14 years, 15-25 years and more than 25 years. The table 2-8-2 also shows the result of the chi-square test carried out to test whether the numbers of observed later admissions in 5 age groups are or are not significantly different from the expected number

of later admissions The chi-square test indicates strongly that number of later asthma admissions in different age groups are significantly different. The table suggests the babies age group (0-2 years old) return to hospital very much more frequently than expected while the asthmatic patients who are more than 7 years old return to hospitals less frequently than expected. It means between previously known asthmatic patients, babies are very much more at risk of returning to hospital than other age groups (both other children age groups and adults).

Table 2-8-3 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes.

Sex	No. of First Admissions (1984-89)	No. of Later Admissions	Expected No. of Later Admissions	$\sum(o_i-e_i)^2/e_i$
Males	12783	8729	8587.3	2.34
Females	11752	7753	7894.7	2.54
Total	24535	16482	16482	χ^2=4.88 d.f.=1

Table 2-8-3 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later asthma admissions for different sexes. This table suggests that the numbers of later asthma admissions in different sexes are significantly different from their expectations. According to this table female patients return to hospital less frequently than it is expected; but, as we shall now see, this conclusion would be misleading[2]. Since we had discovered that the age of an asthmatic patient has a very strong effect on his/her number of later admissions therefore it was decided to investigate

[2] Simpson's Paradox

whether this result is consistent in different age groups or not. To carry out this idea, tables 2-8-4 to 2-4-8 were produced. Each of these tables is due to a particular age group of asthmatic patients. All these tables suggest that the female asthmatic patients return to hospitals more than is expected.

Table 2-8-4 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes for patients who are 0-2 years old.

Sex	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Males	2811	3888	4062.89	7.53
Females	1343	2116	1941.11	15.76
Total	4154	6004	6004	χ^2=23.29 d.f.=1

Table 2-8-5 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes for patients who are 3-6 years old.

Sex	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Males	2240	1557	1630.26	3.29
Females	1081	860	786.74	6.82
Total	3321	2417	2417	χ^2=10.11 d.f.=1

Table 2-8-6 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes for patients who are 7-14 years old.

Sex	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Males	2145	907	947.25	1.71
Females	1186	564	523.75	3.09
Total	3331	1471	1471	χ^2=4.8 d.f.=1

Table 2-8-7 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes for patients who are 15-25 years old.

Sex	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Males	2095	925	1143.24	41.66
Females	3146	1935	1716.76	27.74
Total	5241	2860	2860	χ^2=69.4 d.f.=1

Table 2-8-8 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different sexes for patients who are more than 25 years old.

Sex	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Males	3492	1452	1534.54	4.44
Females	4996	2278	2195.46	3.10
Total	8488	3730	3730	χ^2=7.54 d.f.=1

Note that the three tables which are due to children (tables 2-8-4, 2-8-5 and 2-8-6) show that males are over-represented in first asthma admissions but female children return to hospital more frequently than males. This result leads to this very important indication that maybe male children who had been hospitalised the first time, have not been as ill on average as the female children (who have been hospitalised as the first time). The reason is that female children return to hospital (after first admissions) more than male children. Note that there may be a stronger tendency for doctors to hospitalise male children, rather than female children who are equally ill. The first possibility can be named as "parents' tendency" and the second one as "doctors' or hospitals' tendency" in bringing to hospital or admission male children more than female children when they are equally ill.

Table 2-8-9 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later asthma admissions in different types of marital status at time of first admission. Only two types of marital status are considered (single and married) and only those asthmatic patients who were more than 15 years were considered. Table 2-8-9 indicates that the single asthmatic patients (never married) return to hospital -after first asthma admission- more frequently than expected while the married asthmatic patients have less later asthma admissions than expected. Simply, these results indicate that single previously known asthmatic patients are more at risk of returning to hospital than married asthmatic patients. This may be because, on average, singles are younger than married patients. Some other contingency tables -which are not introduced here- showed that marital status has no effect on seasonal pattern of both first and later admissions.

Table 2-8-9 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different marital status. For patients who are more than 15 years old.

Marital Status at first admission	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Single	3875	3247	2010.71	27.77
Married	7505	3685	3894.29	14.34
Total	11380	5905	5905	χ^2=42.11 d.f.=1

Table 2-8-10 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later asthma admissions for different types of diagnosis at first admission. As a reminder, type of diagnosis is a covariate which identifies whether a patient had been hospitalised with asthma diagnosis as the first or the second diagnosis. The table indicates that those asthmatic patients whose second diagnosis is asthma, return to hospital very much less frequently than those whose first diagnosis is asthma (which is not an unexpected result).

Table 2-8-11 shows the number of first asthma admissions, the number of later asthma admissions and the expected number of later asthma admissions for different types of admission at first asthma admission. Here all types of admissions have been allocated to either emergency or non-emergency group. Table 2-8-11 suggests that the most of asthma admissions are emergency. This table indicates that the asthmatic patients whose first admission was labelled as non-emergency admission, return to hospital less frequently than is expected.

Table 2-8-10 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different types of diagnosis.

Type of Diagnosis at first admissions	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\Sigma(o_i-e_i)^2/e_i$
Asthma, Second Diagnosis	3243	1290	2178.57	362.42
Asthma, First Diagnosis	21292	15192	14303.43	55.2
Total	24535	16482	16482	χ^2=417.62 d.f.=1

Table 2-8-11 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different types of admissions.

Type of admissions at first admission	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\Sigma(o_i-e_i)^2/e_i$
Non-emergency	1932	830	1297.87	168.66
Emergency	22603	15652	15184.13	14.42
Total	24535	16482	16482	χ^2=183.08 d.f.=1

Table 2-8-12 shows the chi-square tests which were carried to test whether the observed number of later asthma admissions in different cities are significantly different from the expected number of later asthma admissions (which were estimated based on the null hypothesis that the factor "city" has no

effect on number of later asthma admissions.) or not. The table indicates that the city which the asthmatic patient used to live in, has a significant effect on his/her number of later asthma admissions. Here a patient's city is defined as the city that the patient was living in at time of first asthma admission and it is assumed that other admissions (if there were any for this patient) also were occurred in same city[3]. Table 2-8-12 suggests that the asthmatic patients in different cities may have less or more later asthma admissions than expected. The biggest difference in number of later asthma admissions and its expectations are due to cities Motherwell, Glasgow, Edinburgh and Dundee. According to table 2-8-12, the asthmatic patients who live in Motherwell and Edinburgh return to hospitals (or being hospitalised) more frequently while those who live in Dundee, Glasgow or Paisley return less frequently. It implies

Table 2-8-12 : Chi-square test for comparing the numbers of later asthma admissions in a 3 years horizon after first asthma admission with the expected number of later admissions in different cities.

City of first admissions	No. of First Admissions	No. of Later Admissions	Expected No. of Later admissions	$\sum(o_i-e_i)^2/e_i$
Aberdeen	2279	1595	1605.96	0.07
Dundee	1549	996	1091.55	8.36
Edinburgh	4278	3174	3014.61	8.43
Glasgow	5484	3679	3864.45	8.9
Kilmarnock	1795	1281	1264.9	0.21
Motherwell	1718	1394	1210.64	27.77
Paisley	1602	1062	1128.89	3.96
Total	18705	13181	13181	χ^2= 57.71 d.f.=6

[3] Only around 800 out of 40496 patients had a subsequent admission in a different city.

that in some cities either the asthmatic patients are more ill or the hospitals hospitalise the asthmatic patients more easily. Note that these results are preliminary results and may not be very accurate. If one is interested to find out more about the effect of city on number of later admissions then he/she should see the more formal analyses in chapter 4.

Many contingency tables were produced to investigate the effect of different factors on seasonal pattern of first and later asthma admissions. Here it is not very useful to present all these contingency tables. We just mention the results of these tables. Some of these tables indicate that age of asthmatic patients (at time of first asthma admission) has a very important effect on seasonal pattern of both first and later asthma admissions. See 2.4 above. Some other contingency tables suggested while type of diagnosis at first asthma admission has significant effect on seasonal pattern of first admission of some asthmatic patients (i.e. in some age groups), it has not any effect on seasonal pattern of later asthma admissions. This was the case for the factor city as well. i.e. in some cities the seasonal pattern of first asthma admissions, in some age groups, are different. Some other contingency tables showed that, in all age groups, the factor "year of first asthma admission" has significant effect on seasonal pattern of first admission i.e. different cohorts of first admission have different seasonal pattern.

2-9 : Summary :

In 2-1 we mentioned the modifications which were done on initial data set. In this section we also explained that the later admissions of asthmatic patients were considered in a 3 year horizon after their first admission. In 2-2 the precision of this choice was investigated.

In 2-3 we showed the frequency of first admissions in different levels of different factors.

In 2-4 the existence of seasonal changes in occurrence of first and later admissions was reported. We showed that the maximum number of first admissions for children (up to 14 years old) happens in September and for patients who are 15-25 years old in November.

In 2-5 we reported the rates of first asthma admission in different years, age groups, sexes and cities. We also discussed the changes over years. We showed that the rate of first asthma admission has sharply increased for babies. Among cities, two cities Dundee and Edinburgh, with respectively 1.03 and 1.06 first admission per 1000 population, had the highest rates of first admission. We also showed that even the ratio of number of later admissions (in a 3 year horizon) to first admissions for babies has changed significantly over years 1984 to 1992, but changes in none of age groups are important.

In 2-6 we reported the existence of fashions in Scotland's cities in diagnosis of the type of asthma disease for children (up to 14 years old) and we concluded that the factor "type of asthma" is not a valid factor to be considered in further analyses.

In 2-7 the intensity of patients' later admissions in different years after first admission (up to fifth year) was discussed. We showed that the intensity of having a later admission decreases as the years pass. Different cohorts of first

admission had similar trend except cohort 1987 (in 7-14 and 15-25 years old patients). Babies had greater intensities than other age groups but after 5 years after first admission, patients in all age groups had very similar intensity of later admissions.

In 2-8 the relation between later admissions and some factors was investigated (one factor each time). It was shown that the intensity of later admissions is associated with age group (especially babies), with cohort of first admission, or with city. We also showed that males are over-represented in first admissions but female children return to hospital more frequently than males.

Chapter 3

Modelling the number of first asthma admissions (Using the Log Linear Model)

In section 2-3 we claimed that all factors, year of first asthma admission, month of first asthma admission (season), marital status, age group, city and sex are related, when considered individually, to the number of first asthma admission. We remind the reader that these admissions are due to new asthmatic patients. In this chapter a formal model called "Log Linear Model" is going to be used to model the number of first asthma admissions. In section 3-2 some primary aspects of these types of model will be illustrated to give the reader some idea about these models before going through the results. In section 3-1 we give the reason(s) for choosing a particular set of covariates (from the list of all covariates) to be used in modelling the first asthma admissions. In this section we also will define different types of first asthma admissions and then will model each type separately.

3-1 : Different Types of Factor[1] :

To carry out our idea in dividing the candidate factors in modelling the first asthma admissions, two sets of factors are mentioned here. Reader is referred to appendix 1 to see a list of possible factors and their definitions. Consider the factors such as admission type, diagnosis type and asthma type (maybe as well as specialty, hospital, discharge code and type of facility) as one group of factors and the factors such as sex, age group, year of first asthma admissions, and city as another group of factors.

What is the difference between these two types of factors? The factors such as "sex", "age group", "year of first admission", "marital status" and "city" are the factors which are characteristics of the individual at the time of first asthma admission. These factors accompany the individual for all his life in our study and we are interested to find out the relation between these factors and the event of asthma admission for a particular individual (i.e. for a group of patients who have similar values for all these factors). Hence these factors are explanatory variables. However the factors such as "admission type", "asthma type", "diagnosis type" and maybe "season" (i.e. the month of asthma admission) are the factors which are not characteristics of the individual in advance (at least until the time of first asthma admission). These factors are measured at the time of occurrence of the asthma admission event and identify the type of hospitalisation, or more clearly the type of response, rather than being the explanatory variables.

In this chapter we are going to consider the factors sex, age group, city and the year of admission (and probably marital status) as the explanatory

[1] A list of all covariates and their definitions are included at the end of the thesis as "Appendix 1".

variables and will fit some Log Linear models using these factors to different types of first asthma admission. By different types of first asthma admission we mean different numbers of first asthma admissions in different combination of the factors admission type, diagnosis type, asthma type, discharge code, type of facility, hospital and specialty. In identifying the different types of first admissions, none of these mentioned factors except admission type and diagnosis type was used. The reasons for not considering the other factors are as follows. The factor asthma type was not considered because it is no longer a valid factor in modelling the number of first asthma admissions (because of fashions in diagnosis of type of asthma, see section 2-6). The factors discharge code, type of facility were not considered because almost all first asthma admissions belonged only to one level of these factors- see section 2-3. Other factors such as specialty and hospital also were not used because of problem with small counts- see section 2-3. Therefore we consider only 4 types of first admission due to different combination of two factors admission type and diagnosis type. The factors season was also ignored due to practical problems due to small counts.

3-2 : Introduction to Log Linear Models:

The observed counts in a contingency table are often regarded as independent Poisson random variables.

A loglinear model assumes a simple factorial form for the logarithms of the Poisson parameters, corresponding to the various cell of the contingency table.

An additive model of this kind, that is having main effects only, corresponds to no association between the various factors (rows, columns, ... of the table). Interest tends to focus, therefore, on any interactions in the model.

In the GLIM[2] statistical package(GLIM 4 1994), used here, the term "scaled deviance" stands for the likelihood ratio statistic $2\log\lambda$ for testing a model within the saturated model. The null distribution of $2\log\lambda$ is approximately χ^2.

Since we are going to use the standardised Pearson (Atkinson A.C. 1985, McCullagh P. 1989, Williams D.A. 1987, GLIM 4 1994) residuals to investigate the goodness of fit of the models it is a good idea to define this type of residuals. The Pearson residuals for the poisson counts are defined as :

$$r^{p}_{i} = (y_i - \hat{\mu}_i)/\sqrt{\hat{\mu}_i}$$

while the standardised Pearson residuals are defined as:

$$r^{ps}_{i} = r^{p}_{i} /\sqrt{(1-h_i)}$$

[2] The statistical package for Generalised Linear Interactive Modelling version 4.

where h_i are the diagonal entries in the hat-matrix,

$$H=V^{-(1/2)}X(X'V^{-1}X)X'V^{-(1/2)}.$$

The standardised Pearson residual (compared to the Pearson residual) has a very important advantage that it takes into account the fact that $\hat{\mu}_i$ are merely estimates of μ_i and hence are correlated with the responses y_i. The estimated variance should ideally take into account this correlation. It is therefore desirable to adjust the Pearson residuals by dividing it by a factor (i.e. dividing by $\sqrt{(1-h_i)}$) which compensates for the correlation between y_i and $\hat{\mu}_i$. In all our models' goodness of fit investigation, we will use the standardised Pearson residuals.

3-3 : Modelling different types of first asthma admissions :

Here we are going to model different types of first admission by log linear model. As was said before, 4 types of first admission exist which are the result of combination of two factors admission type and diagnosis type. We name these 4 types of first asthma admissions as "first asthma admissions

Table 3-3-1 : Different types of first asthma admissions which were used to be modelled

	Non-emergency Admission (Total Numbers) (Numbers Used)	**Emergency Admission (Total Numbers) (Numbers Used)**	**Total (Total Numbers) (Used Numbers)**
Asthma as first Diagnosis	√ Type 1 (4598) (3600)	√ Type 2 (32771) (26834)	(37369) (30434)
Asthma as second Diagnosis	√ Type 3 (1534) (1302)	√ Type 4 (1593) (1344)	(3127) (2646)
Total (Total Numbers) (Used Numbers)	(6132) (4902)	(34364) (28178)	(40496) (33080)

type 1" to "first asthma admissions type 4". The reason for labelling these 4 types of first admissions is simply to make it easier to recall them. Later we will try to compare these four different models (which are fitted to 4 types of first asthma admissions) to each other to investigate whether the pattern of first asthma admissions is different for 4 types of first admissions or not. Table 3-3-1 shows the 4 types of first admissions. In each cell of this table, two numbers are mentioned, "Total Numbers" and "Used Numbers". The First one, in each cell, is the total number of first asthma admissions of this type which were potentially available for analyses. These are the numbers of first asthma admissions of each type in the whole of Scotland from January 1984 to December 1992. The second number, in each cell, is the number of first asthma admissions in 8 cities which we decided to be used for analyses. Later it was discovered that the number of first asthma admissions in one of these cities (the region Fife[3]) has not been collected for the whole period of study. We therefore decided to ignore the data correponding to this region. The numbers of first asthma admissions of each type, in sections later than 3-4 is slightly less than the second numbers in table 3-3-1.

[3] This region is north of the river Forth. The region actually corresponds to the Fife Health Board which for confidentiality reasons used its own post code system.

3-4 : A Model For Emergency First Diagnosed First Admissions (first admissions, type 2), Including All Explanatory Variables :

In this section we intend to fit a log linear model to number of first asthma admissions, including all explanatory variables. We remind the reader that we called these first admissions as "first asthma admissions type 2". The reason that we chose this type is that it is the most common. This model will not be exactly the model which we may decide to fit to different types of first admissions. The main objective of this section (i.e. fitting a model including all explanatory variables) is to investigate which explanatory variable (s) is important to be used in final modelling or which levels of an explanatory variable(s) could be pooled together (without losing too much information) to have larger counts in the remaining levels and, as the result, obtaining a better fit for the model. Hence when some levels of an explanatory variable are pooled we will have fewer parameters in the fitted model. Therefore we could claim that by pooling different levels of an explanatory variable, in some way that not much information is lost, we may have both a better fit (because of large count in each level) and fewer parameters in the fitted model.

In this section the decision for choosing the important explanatory variables, or for choosing those levels of an explanatory variables which should be pooled, will be made by investigating some simple plots of actual and estimated counts (from the fitted model) against the different factors. Note we are not going to use any formal test for making the decisions. The reason is that

we are dealing with a very large data set therefore every small difference, say for example between number of first admissions in different cells, will be significant but it does not necessarily mean that the difference is important. This type of decision (considering importance rather than significance) is quite useful and much more practical when one is dealing with a very large data set. Later, in all model fitting procedures and in making most decisions we will use this idea as well.

As was said before, in this intermediate model, we will use all recorded explanatory variables. By all explanatory variables we mean all of those factors which were mentioned as explanatory variables in section 3-1 and not those which were identified as the type of response variables. These explanatory variables are "city", "year of admission", "age group", "marital status" and "sex". Because of the problem that there is not any married patient in children age group, this factor (i.e. marital status) should be included in the model in a particular way. We combined the two factors age group and marital status. This new explanatory variable has 7 levels. The levels of age group have been chosen by consideration in literature review and also by some consultation with some doctors. The levels of all explanatory variables are as below :

1- f_year[4], has 9 levels due to patients whose first asthma admissions have occurred in year 1984 to 1992. These levels have been coded, respectively, from 1 to 9.

2- f_city[5], has 8 levels due to 7 cities Aberdeen (code 1), Dundee (code 2), Edinburgh (code 3), Glasgow (code 4), Kilmarnock (code 5), Motherwell (code 6), Paisley (code 7) and the region Fife (code 8). These are the cities with the

[4] The letter "f" refers to year of first admission.
[5] The letter "f" refers to the city in which first admission occurred.

most first admissions in Scotland. Other cities are too small to be able to be considered in the analysis.

3- N_agemar[6], this factor has 7 levels which are defined as,

1 : Babies (code 1), who are defined as children aged 2 or less than 2 years old.

2 : Children who are 3-6 years old (code 2).

3 : Children who are 7-14 years old (code 3).

4 : Single young people, 15 to 40 years old (code 4).

5 : Married young people, 15 to 40 years old (code 5).

6 : Single people, more than 40 years (code 6).

7 : Married people, more than 40 years (code 7).

4- Sex : This factor has 2 levels ,

1 : Males (code 1)

2 : Females (code 2)

The contingency table which was constructed by the above mentioned factors had 1008 cells. In a few of these cells the number of first admissions was zero. Recall that the first asthma admissions in this table are only those emergency admissions where asthma has been their first reason of hospitalisation.

Table 3-4-1 shows the model which is fitted to the above contingency table. This model includes all main effects and all two factor interactions except the interaction between the factors f_year and sex and also between f_city and sex. These interaction terms were not significantly related to first asthma admissions. The scaled deviance of this final model is 1046.8 with 833 degree of freedom. This model has 175 parameters. Hence even the scaled deviance indicates there is significant badness of fit, but considering the fact

[6] The letter "n" refers to the word 'new'.

Table 3-4-1 : Fitted Log linear model to number of first asthma admissions of type 2.

	estimate	s.e.	parameter
1	3.719	0.07995	1
2	-0.01213	0.1037	F_YEAR(2)
3	0.09330	0.1034	F_YEAR(3)
4	0.5619	0.09542	F_YEAR(4)
5	0.4675	0.09697	F_YEAR(5)
6	0.2446	0.1001	F_YEAR(6)
7	0.6889	0.09376	F_YEAR(7)
8	0.7821	0.09291	F_YEAR(8)
9	0.8968	0.09234	F_YEAR(9)
10	-0.4999	0.1094	F_CITY(2)
11	0.5680	0.08639	F_CITY(3)
12	0.8760	0.08305	F_CITY(4)
13	-0.5200	0.1078	F_CITY(5)
14	-0.2707	0.1037	F_CITY(6)
15	-0.5522	0.1092	F_CITY(7)
16	-0.5916	0.1117	F_CITY(8)
17	-0.5869	0.08874	N_AGEMAR(2)
18	-0.6901	0.09114	N_AGEMAR(3)
19	-1.262	0.09669	N_AGEMAR(4)
20	-1.647	0.1074	N_AGEMAR(5)
21	-1.883	0.1085	N_AGEMAR(6)
22	-0.6738	0.08557	N_AGEMAR(7)
23	-0.7510	0.02804	SEX(2)
24	-0.1884	0.1323	F_YEAR(2).F_CITY(2)
25	-0.1564	0.1057	F_YEAR(2).F_CITY(3)
26	-0.1523	0.1027	F_YEAR(2).F_CITY(4)
27	0.01208	0.1290	F_YEAR(2).F_CITY(5)
28	-0.3341	0.1316	F_YEAR(2).F_CITY(6)
29	-0.1296	0.1328	F_YEAR(2).F_CITY(7)
30	0.04887	0.1240	F_YEAR(2).F_CITY(8)
31	-0.3637	0.1367	F_YEAR(3).F_CITY(2)
32	-0.2961	0.1075	F_YEAR(3).F_CITY(3)
33	-0.2064	0.1036	F_YEAR(3).F_CITY(4)
34	-0.07980	0.1313	F_YEAR(3).F_CITY(5)
35	-0.3077	0.1317	F_YEAR(3).F_CITY(6)
36	0.01775	0.1307	F_YEAR(3).F_CITY(7)
37	-0.2424	0.1296	F_YEAR(3).F_CITY(8)
38	-0.4599	0.1272	F_YEAR(4).F_CITY(2)
39	-0.4073	0.09996	F_YEAR(4).F_CITY(3)
40	-0.3958	0.09678	F_YEAR(4).F_CITY(4)
41	-0.1724	0.1226	F_YEAR(4).F_CITY(5)
42	-0.3592	0.1217	F_YEAR(4).F_CITY(6)
43	-0.4717	0.1288	F_YEAR(4).F_CITY(7)
44	-0.4709	0.1232	F_YEAR(4).F_CITY(8)
45	-0.2473	0.1273	F_YEAR(5).F_CITY(2)
46	-0.3498	0.1024	F_YEAR(5).F_CITY(3)
47	-0.2817	0.09876	F_YEAR(5).F_CITY(4)
48	-0.07641	0.1247	F_YEAR(5).F_CITY(5)

49	-0.07424	0.1210	F_YEAR(5).F_CITY(6)
50	-0.07659	0.1258	F_YEAR(5).F_CITY(7)
51	-0.2683	0.1234	F_YEAR(5).F_CITY(8)
52	-0.1590	0.1299	F_YEAR(6).F_CITY(2)
53	-0.1572	0.1041	F_YEAR(6).F_CITY(3)
54	-0.1663	0.1012	F_YEAR(6).F_CITY(4)
55	0.02789	0.1270	F_YEAR(6).F_CITY(5)
56	0.07026	0.1229	F_YEAR(6).F_CITY(6)
57	0.06255	0.1276	F_YEAR(6).F_CITY(7)
58	-0.2664	0.1273	F_YEAR(6).F_CITY(8)
59	-0.4255	0.1260	F_YEAR(7).F_CITY(2)
60	-0.4111	0.09958	F_YEAR(7).F_CITY(3)
61	-0.2071	0.09516	F_YEAR(7).F_CITY(4)
62	-0.2569	0.1235	F_YEAR(7).F_CITY(5)
63	-0.1512	0.1182	F_YEAR(7).F_CITY(6)
64	-0.1212	0.1224	F_YEAR(7).F_CITY(7)
65	-0.4942	0.1234	F_YEAR(7).F_CITY(8)
66	-0.2353	0.1226	F_YEAR(8).F_CITY(2)
67	-0.3056	0.09853	F_YEAR(8).F_CITY(3)
68	-0.2035	0.09488	F_YEAR(8).F_CITY(4)
69	0.01910	0.1194	F_YEAR(8).F_CITY(5)
70	-0.07667	0.1169	F_YEAR(8).F_CITY(6)
71	-0.09009	0.1217	F_YEAR(8).F_CITY(7)
72	-1.534	0.1523	F_YEAR(8).F_CITY(8)
73	-0.4441	0.1255	F_YEAR(9).F_CITY(2)
74	-0.4572	0.09920	F_YEAR(9).F_CITY(3)
75	-0.1973	0.09438	F_YEAR(9).F_CITY(4)
76	-0.1851	0.1217	F_YEAR(9).F_CITY(5)
77	-0.1457	0.1174	F_YEAR(9).F_CITY(6)
78	-0.2595	0.1238	F_YEAR(9).F_CITY(7)
79	-3.164	0.2631	F_YEAR(9).F_CITY(8)
80	0.02268	0.09716	F_YEAR(2).N_AGEMAR(2)
81	0.1541	0.09743	F_YEAR(2).N_AGEMAR(3)
82	0.3829	0.1026	F_YEAR(2).N_AGEMAR(4)
83	0.1104	0.1091	F_YEAR(2).N_AGEMAR(5)
84	0.2816	0.1077	F_YEAR(2).N_AGEMAR(6)
85	0.1253	0.09031	F_YEAR(2).N_AGEMAR(7)
86	0.07903	0.09552	F_YEAR(3).N_AGEMAR(2)
87	-0.05305	0.09950	F_YEAR(3).N_AGEMAR(3)
88	0.1751	0.1047	F_YEAR(3).N_AGEMAR(4)
89	-0.03137	0.1110	F_YEAR(3).N_AGEMAR(5)
90	0.001528	0.1120	F_YEAR(3).N_AGEMAR(6)
91	-0.07263	0.09198	F_YEAR(3).N_AGEMAR(7)
92	-0.07362	0.09028	F_YEAR(4).N_AGEMAR(2)
93	-0.005494	0.09144	F_YEAR(4).N_AGEMAR(3)
94	0.008592	0.09949	F_YEAR(4).N_AGEMAR(4)
95	-0.2723	0.1066	F_YEAR(4).N_AGEMAR(5)
96	-0.1009	0.1052	F_YEAR(4).N_AGEMAR(6)
97	-0.3069	0.08755	F_YEAR(4).N_AGEMAR(7)
98	-0.1195	0.08984	F_YEAR(5).N_AGEMAR(2)
99	-0.1897	0.09273	F_YEAR(5).N_AGEMAR(3)
100	-0.06663	0.09963	F_YEAR(5).N_AGEMAR(4)
101	-0.2058	0.1044	F_YEAR(5).N_AGEMAR(5)
102	-0.1994	0.1059	F_YEAR(5).N_AGEMAR(6)

103	-0.2751	0.08633	F_YEAR(5).N_AGEMAR(7)
104	-0.1447	0.09250	F_YEAR(6).N_AGEMAR(2)
105	-0.1042	0.09402	F_YEAR(6).N_AGEMAR(3)
106	0.1376	0.09924	F_YEAR(6).N_AGEMAR(4)
107	-0.1734	0.1066	F_YEAR(6).N_AGEMAR(5)
108	-0.06700	0.1065	F_YEAR(6).N_AGEMAR(6)
109	-0.08913	0.08659	F_YEAR(6).N_AGEMAR(7)
110	-0.03750	0.08571	F_YEAR(7).N_AGEMAR(2)
111	-0.3174	0.09079	F_YEAR(7).N_AGEMAR(3)
112	-0.01684	0.09533	F_YEAR(7).N_AGEMAR(4)
113	-0.4521	0.1045	F_YEAR(7).N_AGEMAR(5)
114	-0.3275	0.1041	F_YEAR(7).N_AGEMAR(6)
115	-0.5057	0.08562	F_YEAR(7).N_AGEMAR(7)
116	-0.2620	0.08590	F_YEAR(8).N_AGEMAR(2)
117	-0.1875	0.08713	F_YEAR(8).N_AGEMAR(3)
118	-0.1418	0.09462	F_YEAR(8).N_AGEMAR(4)
119	-0.5608	0.1038	F_YEAR(8).N_AGEMAR(5)
120	-0.5904	0.1064	F_YEAR(8).N_AGEMAR(6)
121	-0.6183	0.08502	F_YEAR(8).N_AGEMAR(7)
122	-0.4469	0.08785	F_YEAR(9).N_AGEMAR(2)
123	-0.5072	0.09083	F_YEAR(9).N_AGEMAR(3)
124	-0.1707	0.09481	F_YEAR(9).N_AGEMAR(4)
125	-0.7030	0.1064	F_YEAR(9).N_AGEMAR(5)
126	-0.6533	0.1079	F_YEAR(9).N_AGEMAR(6)
127	-0.6235	0.08513	F_YEAR(9).N_AGEMAR(7)
128	0.5271	0.09557	F_CITY(2).N_AGEMAR(2)
129	0.4300	0.09979	F_CITY(2).N_AGEMAR(3)
130	0.4674	0.09823	F_CITY(2).N_AGEMAR(4)
131	0.4115	0.1169	F_CITY(2).N_AGEMAR(5)
132	0.4435	0.1135	F_CITY(2).N_AGEMAR(6)
133	0.3089	0.09640	F_CITY(2).N_AGEMAR(7)
134	0.3327	0.07538	F_CITY(3).N_AGEMAR(2)
135	0.3209	0.07770	F_CITY(3).N_AGEMAR(3)
136	0.2645	0.07740	F_CITY(3).N_AGEMAR(4)
137	0.4149	0.09021	F_CITY(3).N_AGEMAR(5)
138	0.4271	0.08794	F_CITY(3).N_AGEMAR(6)
139	0.4497	0.07228	F_CITY(3).N_AGEMAR(7)
140	0.3344	0.07041	F_CITY(4).N_AGEMAR(2)
141	0.2752	0.07296	F_CITY(4).N_AGEMAR(3)
142	0.1820	0.07277	F_CITY(4).N_AGEMAR(4)
143	0.2614	0.08610	F_CITY(4).N_AGEMAR(5)
144	0.06832	0.08589	F_CITY(4).N_AGEMAR(6)
145	0.1964	0.06923	F_CITY(4).N_AGEMAR(7)
146	0.5038	0.09075	F_CITY(5).N_AGEMAR(2)
147	0.5859	0.09199	F_CITY(5).N_AGEMAR(3)
148	0.1678	0.09806	F_CITY(5).N_AGEMAR(4)
149	0.3582	0.1119	F_CITY(5).N_AGEMAR(5)
150	0.4856	0.1066	F_CITY(5).N_AGEMAR(6)
151	0.4864	0.08848	F_CITY(5).N_AGEMAR(7)
152	0.4553	0.08664	F_CITY(6).N_AGEMAR(2)
153	0.5216	0.08828	F_CITY(6).N_AGEMAR(3)
154	0.06558	0.09446	F_CITY(6).N_AGEMAR(4)
155	0.2879	0.1077	F_CITY(6).N_AGEMAR(5)
156	0.04539	0.1107	F_CITY(6).N_AGEMAR(6)

157	0.1203	0.08901	F_CITY(6).N_AGEMAR(7)
158	0.7071	0.08983	F_CITY(7).N_AGEMAR(2)
159	0.5777	0.09416	F_CITY(7).N_AGEMAR(3)
160	0.3686	0.09651	F_CITY(7).N_AGEMAR(4)
161	0.2899	0.1160	F_CITY(7).N_AGEMAR(5)
162	0.2105	0.1153	F_CITY(7).N_AGEMAR(6)
163	0.3538	0.09236	F_CITY(7).N_AGEMAR(7)
164	0.4971	0.1078	F_CITY(8).N_AGEMAR(2)
165	0.5838	0.1089	F_CITY(8).N_AGEMAR(3)
166	0.2725	0.1150	F_CITY(8).N_AGEMAR(4)
167	0.6658	0.1226	F_CITY(8).N_AGEMAR(5)
168	0.8790	0.1153	F_CITY(8).N_AGEMAR(6)
169	1.015	0.09677	F_CITY(8).N_AGEMAR(7)
170	0.03456	0.04321	N_AGEMAR(2).SEX(2)
171	0.1592	0.04406	N_AGEMAR(3).SEX(2)
172	1.087	0.04492	N_AGEMAR(4).SEX(2)
173	1.411	0.05222	N_AGEMAR(5).SEX(2)
174	1.740	0.05420	N_AGEMAR(6).SEX(2)
175	0.8730	0.04113	N_AGEMAR(7).SEX(2)

Scalled Deviance : 1046.8 with 833 d.f.

that we are dealing with large number of cells, the scaled deviance is not very different from the degrees of freedom.

Plots 3-4-1 and 3-4-2 show, respectively, the scatter plot of the standardised Pearson residuals against the estimated count, and the estimated count against the actual count. Plot 3-4-1 indicates that even there is a slight decrease in variance of residuals for large counts but it is not unlikely to be just by chance. Plot 3-4-2 indicates the model is fairly well fitted for practical purposes and fitted values are fairly close to actual counts. For instance, where the estimated count is 25 we should expect the majority of actual counts to lie between $25 \pm 1.96\sqrt{25} = (15 , 35)$: this seems to be so.

Considering the fact that the model of table 3-4-1 is fairly well fitted, we present some plots to investigate the importance of the main effects and the interaction effects which are included in the model. As was said before by considering these plots we may discover which explanatory variables should be considered in later modelling and also which levels of the factors are possible to be pooled. Before going through this, it is good idea to present the mathematical form of the mentioned model. This log linear model is :

$$\text{Log } \mu_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\alpha\delta)_{il} + (\beta\gamma)_{jk}$$

where,

i = N_agemar

j = f_city

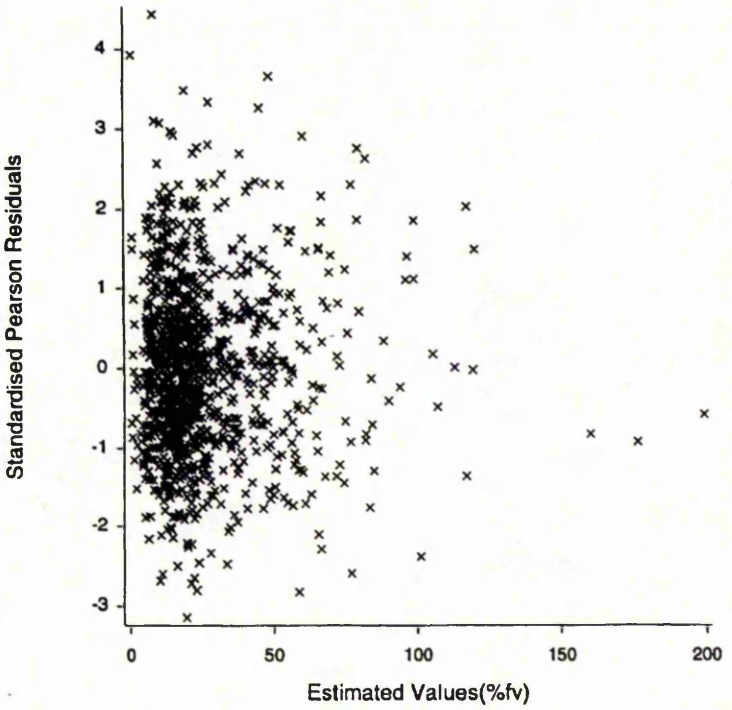
k = f_year

l = sex

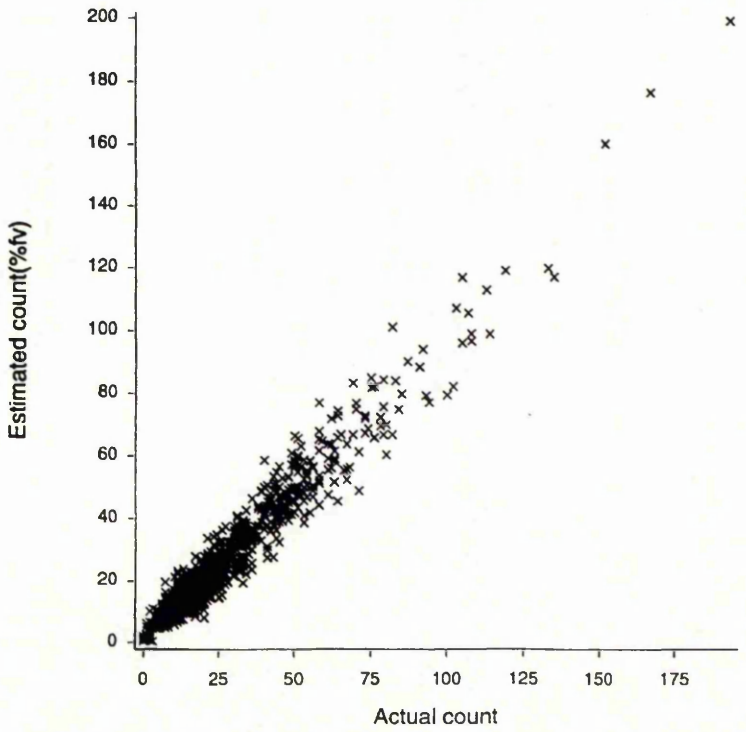
and μ_{ijkl} is the estimated parameter for the Poisson distribution which has been assumed for the cell with ith N_agemar, jth f_city, kth f_year and lth sex.

We are particularly interested to investigate whether the factor marital status is needed in the model or not. We are also interested to pool some cities

Plot 3-4-1 : Scatter plot of standardised pearson residuals against the fitted valuse for model of table 3-4-1.



Plot 3-4-2 : Scatter plot of estimated number of first asthma admissions against actual number of first asthma admissions (model of table 3-4-1).



and also some levels of age groups together. Hence to make correct decision we need to investigate all interaction terms in the model involving one of these factors. The main effects of N_agemar and f_city are not of much interest. The reason is we do not know[7] the size of population of each level of these factors. Any difference in main effects may therefore be simply the result of differences in the size of the relevant population in different cities or different age groups. Table 3-4-2 shows all interaction terms which are included in the model. Main effects are indicated on the diagonal. Note, for example to make some decision for pooling some cities, we should look at the plots which show the interactions between the factors "city" and "N_agemar" and also those plots which show the interactions between "city" and "f_year".

Table 3-4-2 : Main effects and 2-factors interaction terms which are included in model of table 3-4-1.

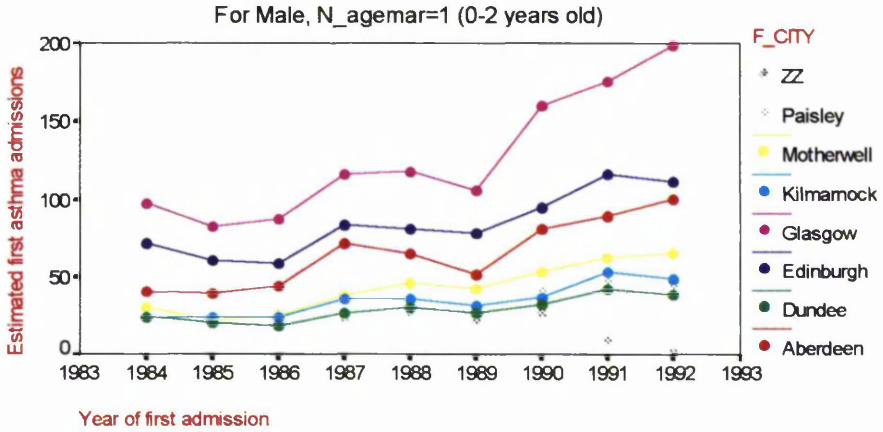
	N_agemar	f_city	f_year	sex
N_agemar	√	√	√	√
f_city		√	√	–
f_year			√	–
sex				√

We first begin with the idea of pooling some cities together. 14 plots were produced to investigate which cities could be pooled without losing so much information. 7 of these plots showed the scatter plots of estimated (expected) count against the factor f_year showing the pattern of changes in each city at particular levels of factor N_agemar. The other 7 plots were similar to first group of plots but were produced for actual counts. Note each of these

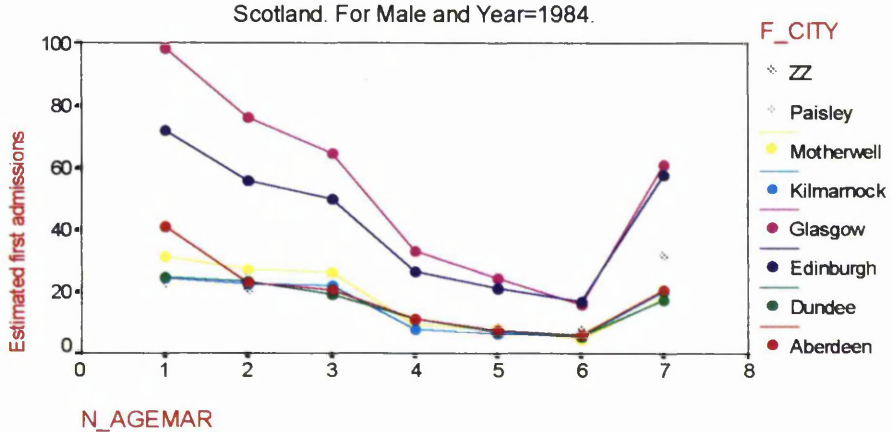
[7] The population sizes did not exist in annual reports or in census reports in the form required here i.e. by age group and city.

plots stands for the interaction (association) between f_city and f_year in each level of N_agemar. Considering the number of plots which we should prepare to make the decision for pooling levels of other factors, we have too many plots to be able to present all of them here. We decided not to present those plots which correspond to actual count and from those which are due to estimated (expected) count, only present one from each group. Accordingly, only one of the above 14 plots, just as a sample, is shown. This is plot 3-4-3 shows the scatter plot of estimated count against the factor f_year showing the pattern of changes in each city for male babies. It is difficult to make any definite decision as to which cities should be combined. Note different researchers may come to different results. All plots suggest cities coded as 2 and 5 which are due to Dundee and Kilmarnock show very similar pattern. The city Paisley also shows fairly similar pattern to these two cities. It means the interactions which exist between these three cities and f_year is similar. Therefore we could pool these cities together without losing considerable information i.e. the pooled group of cities which is a mixture of these three cities could stand for the interaction between these cities and the factor f_year. We noticed that even in some N_agemar's levels the city Motherwell (which is coded as 6) is very close to this group of cities but in some other levels it is so different as not to be pooled into this group of cities. It was noticed also the city coded as 8 has a very strange pattern after year 1991 in all levels of N_agemar. There were no first asthma admissions corresponding to this city in year 1992. Note more comment could be made for pattern of first admissions in each city and in each level of N_agemar over year 1984 to 1992, but we leave these comments to be given when the final model is fitted to the emergency first diagnosed admissions.

Plot 3-4-3 : Patterns of changes in numbers of estimated first asthma admissions in years 1984-92 in different cities of Scotland.



Plot 3-4-4 : Patterns of changes in numbers of estimated first asthma admissions in different levels of n_agemar and different cities of Scotland. For Male and Year=1984.



The reader should be aware that the final decision in pooling some cities together could not be made just by considering the above mentioned plots (one of which is presented as plot 3-4-3). The reason is that the interactions due to f_city*N_agemar are also included in the model of table 3-4-1 and these three cities may have different interaction with the factor N_agemar. 18 plots (9 plots for estimated count and 9 plots for actual count) which were produced to investigate whether any of the three cities has different interaction with the

factor N_agemar or not, indicated that it is not the case i.e. all three cities have fairly similar interaction with N_agemar. One of these plots is shown as plot 3-4-4. These groups of plots are plots of, respectively, estimated and actual count against the factor "N_agemar" for different year of admission (f_year). In each of these plots the pattern of estimated (or actual) count in different cities are shown. These plots also indicate that since the pattern due to these cities (Dundee, Kilmarnock, Paisley as previously mentioned) are fairly proportional these cities may be pooled without losing so much information. A mathematical justification appears at end of this section 3-4.

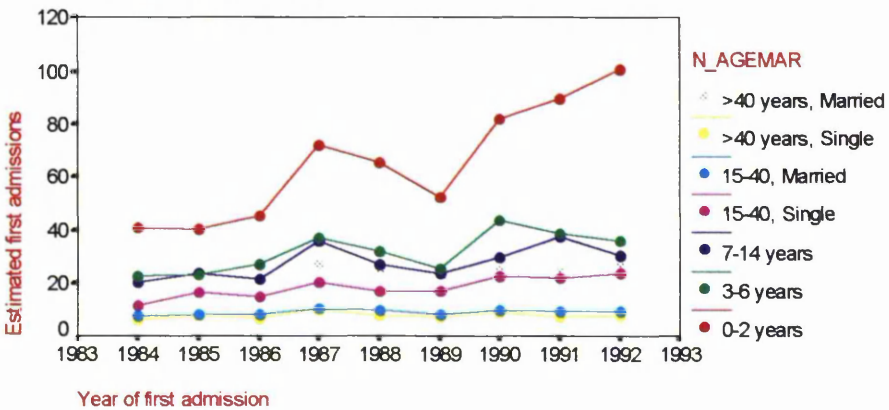
The next factor which we are interested to investigate whether it is related to first admissions or not is "marital status". As was said before, "marital status" was included in the model as a mixture factor with age group. The factor N_agemar, which includes the "marital status", has interaction with all factors f_year, f_city and sex. It means for investigating whether we could or could not ignore the factor "marital status" (i.e. pooling levels 4,5 and 6,7 of the factor N_agemar), we must study the interactions between N_agemar and all other factors. One other interest exists in studying the interaction between the factor N_agemar and all other factors. This interest is that we would like to investigate whether it is possible to mix some level of age groups or not.

16 plots were produced for investigating whether we could or could not ignore the factor "marital status" or pool some levels of the factor "N_agemar". These plots showed the scatter plot of, respectively, estimated count and actual count for different level of N_agemar against the year of admission for each city. Note that each of these plots illustrates the interaction between the two factors N_agemar and f_year in a particular city. Only one of these plots is presented here (plot 3-4-5). The plots indicate two age groups 2 and 3 which are due to 3-6 and 7-14 years old children and four age groups 4, 5, 6 and 7,

which are respectively, due to single 15-40 , married 15-40, single more than 40 and married more than 40 years old, in all cities have similar pattern. Note groups 2 and 3 (children) have more or less proportional patterns, and groups 4, 5, 6, 7 (adults, whether single or married) have more or less proportional patterns (except perhaps single 15-40 years i.e. group 4). It means, as far as the interaction between the factors N_agemar and f_year is concerned, two age groups 2 and 3 together and four age groups 4, 5, 6 and 7 could be pooled without losing much information. Pooling all groups 4 to 7, means we could ignore the factor "marital status" as an explanatory variable. About these series of plots two comments are needed. First, in all cities most increase in number of first admissions is due to increase in number of asthmatic babies (0-2 years old) and also due to "single 15-40 years old" patients (group 4) which could be related to increase in number of homeless people in recent years. Second comment is that the region Fife has shown a very strange behaviour and all counts in this city decrease to zero in year 1992. Since the data for this region (code 8) does not seem reliable we will delete this region in later analysis.

Plot 3-4-5 : Patterns of changes in numbers of estimated first asthma admissions in years 1984-92, in different levels of n_agemar in Scotland

For Male and Year=1984.

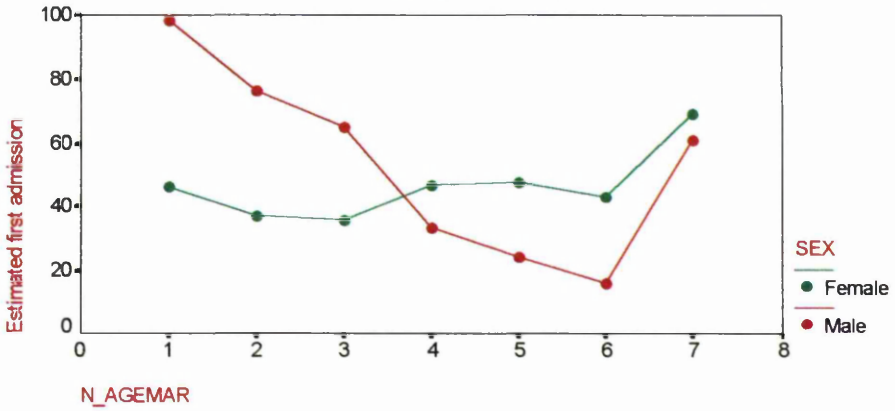


As was said before, to make the final decision for pooling different levels of factor N_agemar, we need to study the other interaction terms involving the factor N_agemar. Some of the previously prepared plots can be used to investigate the interaction between f_city and N_agemar. These are the plots of which plot 3-4-4 was representative. Examination of the interaction between the f_city and N_agemar suggests it is possible to combine two age groups 2 and 3. The reason for agreement for this combination is that the estimated count in age group 3 in different cities and in different year of first admission could be calculated by multiplying a single constant to related number of estimated count in age group 2. In an easier sense, the reason is that the patterns of changes in estimated count from age group 2 to age group 3 in almost all cities are proportional. By same reason the age group 4 and 5 and also the age groups 6 and 7 could be combined, thus ignoring the factor "marital status" in later modelling. There is not any definite right answer to the question of whether it is possible to pool these 4 levels of the factor N_agemar. In some cities like Glasgow and Edinburgh (in some years) it would be more difficult to justify pooling of these cities but in the rest of cities it seems logical to combine the last 4 levels of N_agemar.

The last factor whose interaction with N_agemar we should investigate is the factor "sex". Plots 3-4-6 and 3-4-7 show, respectively, the estimated count and the actual count in different levels of N_agemar in different sexes for Glasgow at year 1984. Note that since no interaction due to f_year or f_city with sex is included in the model therefore for studying the interaction between N_agemar and sex, a particular f_city/f_year combination is enough. Hence if the pattern of interaction between N_agemar and sex in different cities and

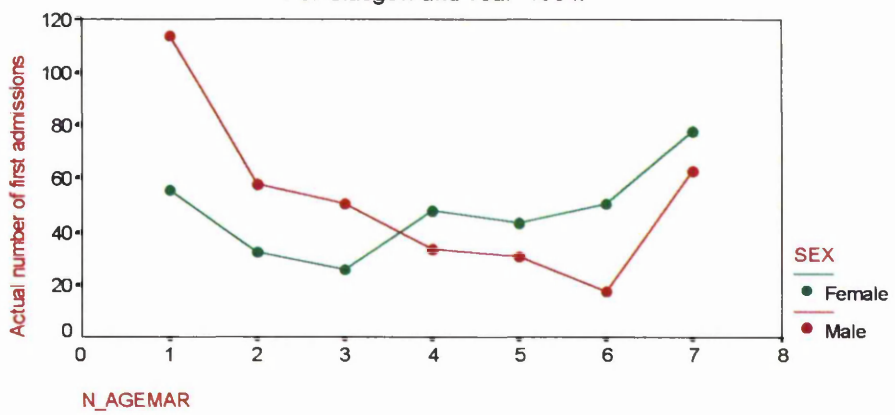
Plot 3-4-6 : Patterns of changes in numbers of estimated first asthma admissions in different levels sex and n_agemar in Scotland.

For Glasgow and Year=1984.



Plot 3-4-7 : Patterns of changes in actual numbers of first asthma admissions in different levels sexes and n_agemar in Scotland.

For Glasgow and Year=1984.



different years were plotted, all of them would show a similar pattern as plot 3-4-6. These two plots indicate the two age groups 2 and 3 and also four groups 4 to 7 could be pooled together. The reason is that those part of patterns which are due to these groups are roughly proportional.

As the result we discover that we could have a simpler model than the model of table 3-4-1. Hence we came to this result that not only could we ignore the factor marital status but also we could pool two age groups 2 and 3 together and also four age groups 4, 5, 6 and 7 together. It means in later

models we will have only 3 age groups which could be defined as 0-2 years (babies), 3-14 years (children) and more than 14 years(adults). Note that cities Dundee, Kilmarnock and Paisley could also be pooled together. We also discovered that region Fife, since it has no first admissions in year 1992 and too few first admissions in year 1991 (which suggests some first admissions have not been included in the data), should be deleted from the analysis. In next models we will use factors city, year of admission, age group and sex, with these new mentioned levels, to fit 4 separate log linear models to the 4 types of first admissions that were mentioned before. To fit these four log linear models, we constructed a contingency table by using the 4 mentioned factors. This contingency table has 270 cells and in each cell it contains either first admissions type 1, type 2, type 3 or type 4.

So far we decided to pool some cities together as well as some age groups and we claimed since the pattern of admissions in these cities or age groups are proportional the new model which will be fitted to data, using these new factors, will have a fit as good as previous model (model of table 3-4-1). In this section it is intended to prove this claim mathematically.

Suppose, i= N_agemar

j= f_city

k= f_year

l= sex,

then the model of table 3-4-1 could be written as :

$$\text{Log } \mu_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\alpha\delta)_{il} + (\beta\gamma)_{jk} \qquad (1)$$

Suppose we intend to compare two cities j_1 and j_2 , for fixed N_agemar, f_year and sex. Then we have

$$\text{Log}(\mu_{ij_1kl} / \mu_{ij_2kl}) = \log \mu_{ij_1kl} - \log \mu_{ij_2kl}$$

$$= \beta_{j_1} - \beta_{j2} + (\alpha\beta)_{ij_1} - (\alpha\beta)_{ij_2} + (\beta\gamma)_{j_1k} - (\beta\gamma)_{j_2k} \qquad (2)$$

The above expression has an interesting interpretation if and only if it depends on i, or on k, or on both. Thus the ratio of expected counts, for two particular cities j_1 and j_2, shows interesting association(s) if it depends on the factor N_agemar and/or on the factor f_year. It does not depend on sex, according to the model being considered.

Where j_1 and j_2 are, respectively, Dundee and Kilmarnock (for instance), we see in plots such as 3-4-4 and 3-4-3 that :

(a) For l=male, fixed k

$\mu_{ij_1kl} / \mu_{ij_2kl}$ does not depend on i,

i.e. the patterns are proportional over N_agemar.

(b) For l = male, fixed i

$\mu_{ij_1kl} / \mu_{ij_2kl}$ does not depend on k,

i.e. the patterns are proportional over years.

It follows from (a) that the differences

$(\alpha\beta)_{ij_1} - (\alpha\beta)_{ij_2}$ (i=1, 2, ..., 7),

in equation (2), are all equal, and therefore equal to zero (recalling GLIM's convention $(\alpha\beta)_{1j} = 0$ for (j=1, .., 8)). Thus $(\alpha\beta)_{ij_1} = (\alpha\beta)_{ij_2}$ for (i=1, 2, ..., 7).

It follows similarly from (b) that,

$(\beta\gamma)_{j_1k} - (\beta\gamma)_{j_2k}$

are all zero (k=1, 2, ..., 9). So $(\beta\gamma)_{j_1k} = (\beta\gamma)_{j_2k}$ for k=1, 2, ..., 9. Note it was shown if the pattern of two cities are proportional then all interaction terms involving one of these cities is equal to the similar interaction term involving the other city.

Returning to equation (2) above, we see that the comparison between Dundee and Kilmarnock is not interesting, because the ratio $\mu_{ij_1kl} / \mu_{ij_2kl}$ does

not depend on i, k and l (N_agemar, year and sex). It represents only a main effect, including differences in population size as we show,

Pooling Dundee and Kilmarnock ($j=j_1,j_2$) will give a combined city ($j=j_{1+2}$) and,

$$\mu_{ij_{1+2}kl} = \mu_{ij_1kl} + \mu_{ij_2kl}$$

$$=\exp(\mu+\alpha_i+\beta_{j_1}+\gamma_k+\delta_l+(\alpha\beta)_{ij_1}+(\alpha\gamma)_{ik}+(\alpha\delta)_{il}+(\beta\gamma)_{j_1k})$$

$$+\exp(\mu+\alpha_i+\beta_{j_2}+\gamma_k+\delta_l+(\alpha\beta)_{ij_2}+(\alpha\gamma)_{ik}+(\alpha\delta)_{il}+(\beta\gamma)_{j_2k})$$

since $(\alpha\beta)_{ij_1} = (\alpha\beta)_{ij_2}$ for i=1, 2, ..., 7 and also, $(\beta\gamma)_{j_1k} = (\beta\gamma)_{j_2k}$ for k=1, ..., 9 it follows that,

$$= \exp(\mu+\alpha_i+\gamma_k+\delta_l+(\alpha\beta)_{ij_1}+(\alpha\gamma)_{ik}+(\alpha\delta)_{il}+(\beta\gamma)_{j_1k})$$

$$\{\exp\beta_{j_1}+\exp\beta_{j_2}\}.$$

Thus ,

$$\log\mu_{ij_{1+2}kl} = \mu+\alpha_i+\log\{\exp\beta_{j_1}+\exp\beta_{j_2}\}+\gamma_k+\delta_l$$

$$+(\alpha\beta)_{ij_{1+2}}+(\beta\gamma)_{j_{1+2}k}$$

$$+(\alpha\gamma)_{ik}+(\alpha\delta)_{il} \qquad (3)$$

Note (3) is same as the unpooled model [equation (1)], except for the main effect of the combined city j_{1+2}.

Above $(\alpha\beta)_{ij_{1+2}} \equiv (\alpha\beta)_{ij_1} \equiv (\alpha\beta)_{ij_2}$,

similarly $(\beta\gamma)_{j_{1+2}k} \equiv (\beta\gamma)_{j_1k} \equiv (\beta\gamma)_{j_2k}$.

Paisley is to be pooled with Dundee and Kilmarnock for similar reasons. Levels 2 and 3 of N_agemar are to be pooled for similar reasons and also levels 4, 5, 6 and 7 of N_agemar.

3-5 : A Model For Non-emergency First Diagnosed First Admissions (admissions type 1):

In this section we fit a log linear model to those non-emergency first admissions which are due to those patients for whom asthma has been their first reason of hospitalisation. We use 4 factors city, year of admission, age group and sex. We will use same sets of factors (with same levels) for other 3 types of first admissions. The level of the factors are as below:

1- Factor "city" :

1 : Aberdeen (code 1)

2 : Edinburgh (code 2)

3 : Glasgow (code 3)

4 : Motherwell (code 4)

5 : Dundee, Kilmarnock and Paisley (code 5)

2- Factor "year of admission" :

9 levels due to years 1984 to 1992. Levels are coded as 1 to 9.

3- Factor "age group" :

1: 0-2 years old (babies) (code 1)

2 : 3-14 years old (children) (code 2)

3 : More than 14 years (adults) (code 3)

4- Factor "sex" :

1 : Male (code 1)

2 : Female (code 2)

Table 3-5-1 shows the model which is fitted to first admissions of type 1. The scaled deviance of the model is 220.64 with 196 degree of freedom. Note that the model is closely fitted. The most important interactions are between age group and sex and also between age group and city. Note, among the main effects of the model, the main effects due to sex and year of admission could be used to claim that there have been more first admissions type 1 due to males than due to females and also, there were some significant changes in number of non-emergency first diagnosed first admissions over years 1984 to 1992. Since we have no information about the size of population in different cities or different age groups, no interpretation could be made for the main effects of these factors.

Table 3-5-1 : Log Linear model fitted to first asthma admission of type 1.

	estimate	s.e.	parameter
1	-3.739	1.155	1
2	0.3020	0.8184	F_YEAR(2)
3	0.9197	0.7399	F_YEAR(3)
4	0.5193	0.9390	F_YEAR(4)
5	0.5159	0.8082	F_YEAR(5)
6	0.5161	0.8199	F_YEAR(6)
7	1.194	0.8002	F_YEAR(7)
8	1.607	0.7261	F_YEAR(8)
9	1.828	0.6954	F_YEAR(9)
10	2.290	1.132	F_CITY(2)
11	3.695	1.067	F_CITY(3)
12	2.559	1.170	F_CITY(4)
13	3.513	1.063	F_CITY(5)
14	4.806	1.148	FAGE_GRP(2)
15	5.027	1.126	FAGE_GRP(3)
16	-0.3228	0.2865	SEX(2)
17	0.3566	0.4877	F_YEAR(2).F_CITY(2)
18	-0.4996	0.4331	F_YEAR(2).F_CITY(3)
19	-0.8084	0.5617	F_YEAR(2).F_CITY(4)
20	-0.2218	0.4476	F_YEAR(2).F_CITY(5)
21	-0.1965	0.4890	F_YEAR(3).F_CITY(2)
22	-0.3497	0.4116	F_YEAR(3).F_CITY(3)
23	-1.280	0.5771	F_YEAR(3).F_CITY(4)
24	-0.2170	0.4277	F_YEAR(3).F_CITY(5)

25	-0.7511	0.4621	F_YEAR(4).F_CITY(2)
26	-1.218	0.3847	F_YEAR(4).F_CITY(3)
27	-2.625	0.7055	F_YEAR(4).F_CITY(4)
28	-1.159	0.4077	F_YEAR(4).F_CITY(5)
29	-0.4272	0.6200	F_YEAR(5).F_CITY(2)
30	-0.08783	0.5038	F_YEAR(5).F_CITY(3)
31	-0.8262	0.6897	F_YEAR(5).F_CITY(4)
32	0.1093	0.5191	F_YEAR(5).F_CITY(5)
33	-0.1554	0.5119	F_YEAR(6).F_CITY(2)
34	-0.8198	0.4430	F_YEAR(6).F_CITY(3)
35	-1.065	0.5894	F_YEAR(6).F_CITY(4)
36	-0.2316	0.4501	F_YEAR(6).F_CITY(5)
37	-1.180	0.5141	F_YEAR(7).F_CITY(2)
38	-1.336	0.4042	F_YEAR(7).F_CITY(3)
39	-1.974	0.6095	F_YEAR(7).F_CITY(4)
40	-0.9358	0.4173	F_YEAR(7).F_CITY(5)
41	-0.8757	0.5123	F_YEAR(8).F_CITY(2)
42	-1.348	0.4214	F_YEAR(8).F_CITY(3)
43	-1.436	0.5724	F_YEAR(8).F_CITY(4)
44	-0.4928	0.4219	F_YEAR(8).F_CITY(5)
45	-0.5970	0.4834	F_YEAR(9).F_CITY(2)
46	-1.251	0.4096	F_YEAR(9).F_CITY(3)
47	-1.050	0.5107	F_YEAR(9).F_CITY(4)
48	-0.4849	0.4122	F_YEAR(9).F_CITY(5)
49	-0.4049	0.7781	F_YEAR(2).FAGE_GRP(2)
50	-0.2554	0.7187	F_YEAR(2).FAGE_GRP(3)
51	-0.6223	0.6953	F_YEAR(3).FAGE_GRP(2)
52	-0.7658	0.6388	F_YEAR(3).FAGE_GRP(3)
53	0.1268	0.9269	F_YEAR(4).FAGE_GRP(2)
54	0.2526	0.8765	F_YEAR(4).FAGE_GRP(3)
55	-2.199	0.8469	F_YEAR(5).FAGE_GRP(2)
56	-0.8570	0.6588	F_YEAR(5).FAGE_GRP(3)
57	-0.4850	0.7814	F_YEAR(6).FAGE_GRP(2)
58	-0.5354	0.7205	F_YEAR(6).FAGE_GRP(3)
59	-0.4637	0.7772	F_YEAR(7).FAGE_GRP(2)
60	-0.7193	0.7216	F_YEAR(7).FAGE_GRP(3)
61	-1.406	0.7052	F_YEAR(8).FAGE_GRP(2)
62	-1.236	0.6291	F_YEAR(8).FAGE_GRP(3)
63	-1.104	0.6543	F_YEAR(9).FAGE_GRP(2)
64	-1.515	0.5999	F_YEAR(9).FAGE_GRP(3)
65	-2.694	1.105	F_CITY(2).FAGE_GRP(2)
66	-1.570	1.083	F_CITY(2).FAGE_GRP(3)
67	-3.246	1.047	F_CITY(3).FAGE_GRP(2)
68	-1.354	1.029	F_CITY(3).FAGE_GRP(3)
69	-2.188	1.143	F_CITY(4).FAGE_GRP(2)
70	-2.134	1.128	F_CITY(4).FAGE_GRP(3)
71	-3.251	1.037	F_CITY(5).FAGE_GRP(2)
72	-1.816	1.021	F_CITY(5).FAGE_GRP(3)
73	-0.3791	0.3291	FAGE_GRP(2).SEX(2)
74	0.6426	0.2929	FAGE_GRP(3).SEX(2)

Plot 3-5-1 shows the histogram of standardised Pearson residuals of the model. Note the mean and the standard deviation of these residuals are very close, respectively, to 0 and 1. Plot 3-5-2 shows the scatter plot of standardised Pearson residuals against the estimated (fitted) values. The plot indicates a few residuals are outside of 95% normal boundary (13/270 = 4.8%). It indicates, even some pattern due to cells with zero, 1 and 2 counts

Plot 3-5-1 : Histogram of standardised Pearson residuals of
model of table 3-5-1.

```
[-3.000,-2.400)  2 S
[-2.400,-1.800)  5 SSS
[-1.800,-1.200) 19 SSSSSSSSSS
[-1.200,-0.600) 51 SSSSSSSSSSSSSSSSSSSSSSSSS
[-0.600, 0.000) 89 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.600) 40 SSSSSSSSSSSSSSSSSS
[ 0.600, 1.200) 28 SSSSSSSSSSSSSS
[ 1.200, 1.800) 19 SSSSSSSSSS
[ 1.800, 2.400)  8 SSSS
[ 2.400, 3.000)  4 SS
[ 3.000, 3.600)  2 S
[ 3.600, 4.200)  1 S
[ 4.200, 4.800)  1 S
[ 4.800, 5.400)  0
[ 5.400, 6.000)  1 S
[ 6.000, 6.600]  0
                        Mean= 0.009   S.D. =1.12
```

are observed in the plot, there is no reason to reject the assumption that count in each cell has a Poisson distribution. Note that the large sample theory could break down for small counts and it could be a reason that larger variance due to small counts are observed in plot 3-5-2. Plot 3-5-3 is the scatter plot of estimated count against actual count. The plot showed the model is fairly well fitted.

Section 3-9 continues the discussion of what this model has to tell us about non-emergency first diagnosed first admissions.

Plot 3-5-2 : Scatter plot of standardised Pearson residuals against the estimated count For model of table 3-5-1

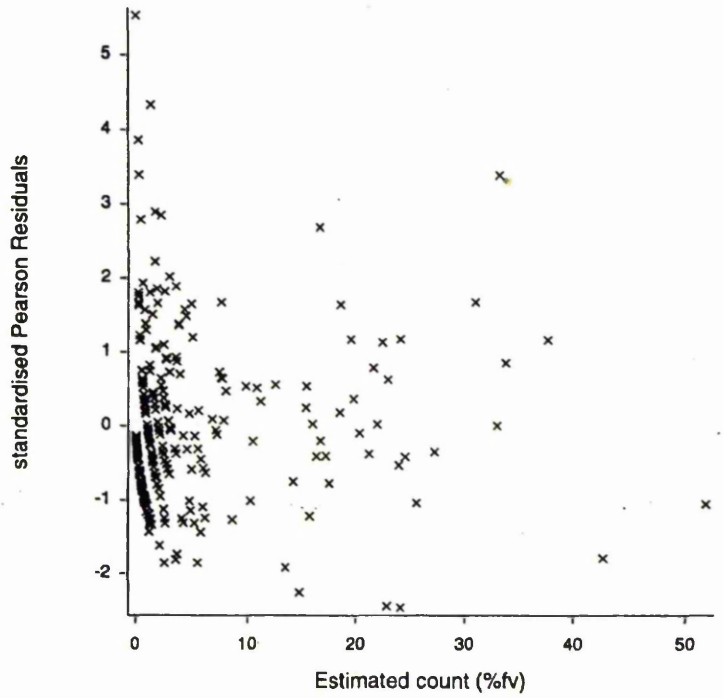
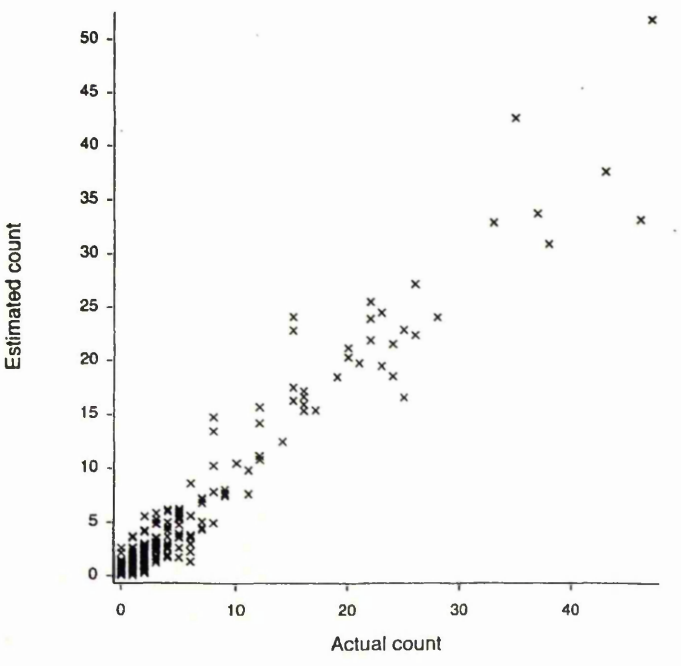


Table 3-5-3 : Scatter plot of estimated count against Actual count for model of table 3-5-1.



3-6 : A Model For Emergency First Diagnosed First Admissions (admissions type 2):

In this section we fit a log linear model to those emergency first admissions which are due to those patients for whom asthma has been their first reason of hospitalisation. We remind the reader that we call this type of first admissions as first admissions type 2. We use same set of factors as were used in the previous model.

Table 3-6-1 shows the model which is fitted to number of new asthmatic patients who have been admitted as emergency and asthma has been their first reason of hospitalisation (i.e. admissions type 2). The model includes 74 parameters and its scaled deviance is 320.3 with 196 degree of freedom. The model, same as the previous model in section 3-5, includes all main effects and all two factor interaction terms except the interactions between sex and year, and sex and city. These 2 interactions were not significant. Note that the model is not exactly fitted i.e. the scaled deviance is significantly larger than its degree of freedom. For three reasons we did not include higher order interaction in the model. First reason is that it is difficult to interpret such interactions. Second, we were interested to fit the same models (i.e. models with same parameters) to all types of first admissions and, as we will see, in all other types of first admissions the model with all main effects and all two factor interaction except interactions due to year*sex and city*sex are well fitted to the data. The third reason is that the model of table 3-6-1, although not exactly fitted, is very well fitted for practical purposes, as we will see. Significant scaled deviance could be only because of large number of

admissions. In addition to all mentioned reasons, the higher order interactions, compared to the number of parameters which they added to the model, were not important.

Table 3-6-1 : Log Linear model fitted to first asthma admissions of type 2.

	estimate	s.e.	parameter
1	3.722	0.08050	1
2	0.006530	0.1047	F_YEAR(2)
3	0.07419	0.1045	F_YEAR(3)
4	0.5670	0.09622	F_YEAR(4)
5	0.4899	0.09766	F_YEAR(5)
6	0.2387	0.1009	F_YEAR(6)
7	0.6837	0.09446	F_YEAR(7)
8	0.7808	0.09326	F_YEAR(8)
9	0.8793	0.09273	F_YEAR(9)
10	0.5621	0.08611	F_CITY(2)
11	0.8829	0.08281	F_CITY(3)
12	-0.2603	0.1033	F_CITY(4)
13	0.5659	0.08516	F_CITY(5)
14	0.05917	0.07636	FAGE_GRP(2)
15	0.1119	0.06986	FAGE_GRP(3)
16	-0.7552	0.02874	SEX(2)
17	-0.1763	0.1052	F_YEAR(2).F_CITY(2)
18	-0.1671	0.1023	F_YEAR(2).F_CITY(3)
19	-0.3579	0.1312	F_YEAR(2).F_CITY(4)
20	-0.1057	0.1040	F_YEAR(2).F_CITY(5)
21	-0.2703	0.1068	F_YEAR(3).F_CITY(2)
22	-0.2045	0.1032	F_YEAR(3).F_CITY(3)
23	-0.2750	0.1303	F_YEAR(3).F_CITY(4)
24	-0.1343	0.1049	F_YEAR(3).F_CITY(5)
25	-0.3984	0.09939	F_YEAR(4).F_CITY(2)
26	-0.4149	0.09651	F_YEAR(4).F_CITY(3)
27	-0.3652	0.1210	F_YEAR(4).F_CITY(4)
28	-0.3533	0.09833	F_YEAR(4).F_CITY(5)
29	-0.3323	0.1018	F_YEAR(5).F_CITY(2)
30	-0.2923	0.09853	F_YEAR(5).F_CITY(3)
31	-0.09136	0.1206	F_YEAR(5).F_CITY(4)
32	-0.1295	0.09965	F_YEAR(5).F_CITY(5)
33	-0.1550	0.1034	F_YEAR(6).F_CITY(2)
34	-0.1869	0.1008	F_YEAR(6).F_CITY(3)
35	0.04939	0.1222	F_YEAR(6).F_CITY(4)
36	-0.02188	0.1018	F_YEAR(6).F_CITY(5)
37	-0.4127	0.09892	F_YEAR(7).F_CITY(2)
38	-0.2208	0.09475	F_YEAR(7).F_CITY(3)
39	-0.1676	0.1175	F_YEAR(7).F_CITY(4)
40	-0.2558	0.09710	F_YEAR(7).F_CITY(5)
41	-0.3177	0.09779	F_YEAR(8).F_CITY(2)
42	-0.2113	0.09427	F_YEAR(8).F_CITY(3)
43	-0.09156	0.1160	F_YEAR(8).F_CITY(4)
44	-0.08219	0.09565	F_YEAR(8).F_CITY(5)

45	-0.4296	0.09828	F_YEAR(9).F_CITY(2)
46	-0.1838	0.09382	F_YEAR(9).F_CITY(3)
47	-0.1542	0.1166	F_YEAR(9).F_CITY(4)
48	-0.2564	0.09643	F_YEAR(9).F_CITY(5)
49	0.05003	0.08646	F_YEAR(2).FAGE_GRP(2)
50	0.2171	0.07874	F_YEAR(2).FAGE_GRP(3)
51	0.03098	0.08580	F_YEAR(3).FAGE_GRP(2)
52	0.04438	0.07892	F_YEAR(3).FAGE_GRP(3)
53	-0.04375	0.07960	F_YEAR(4).FAGE_GRP(2)
54	-0.1812	0.07380	F_YEAR(4).FAGE_GRP(3)
55	-0.1820	0.07958	F_YEAR(5).FAGE_GRP(2)
56	-0.2275	0.07315	F_YEAR(5).FAGE_GRP(3)
57	-0.1153	0.08163	F_YEAR(6).FAGE_GRP(2)
58	-0.01400	0.07440	F_YEAR(6).FAGE_GRP(3)
59	-0.1637	0.07681	F_YEAR(7).FAGE_GRP(2)
60	-0.2973	0.07104	F_YEAR(7).FAGE_GRP(3)
61	-0.2247	0.07468	F_YEAR(8).FAGE_GRP(2)
62	-0.4258	0.06931	F_YEAR(8).FAGE_GRP(3)
63	-0.4840	0.07598	F_YEAR(9).FAGE_GRP(2)
64	-0.4528	0.06900	F_YEAR(9).FAGE_GRP(3)
65	0.3281	0.06286	F_CITY(2).FAGE_GRP(2)
66	0.4585	0.05583	F_CITY(2).FAGE_GRP(3)
67	0.3075	0.05867	F_CITY(3).FAGE_GRP(2)
68	0.2161	0.05263	F_CITY(3).FAGE_GRP(3)
69	0.4865	0.07263	F_CITY(4).FAGE_GRP(2)
70	0.1537	0.06753	F_CITY(4).FAGE_GRP(3)
71	0.5642	0.06017	F_CITY(5).FAGE_GRP(2)
72	0.4003	0.05450	F_CITY(5).FAGE_GRP(3)
73	0.1012	0.03766	FAGE_GRP(2).SEX(2)
74	1.204	0.03430	FAGE_GRP(3).SEX(2)

Plot 3-6-1 : Histogram of standardised Pearson residuals of model of table 3-6-1.

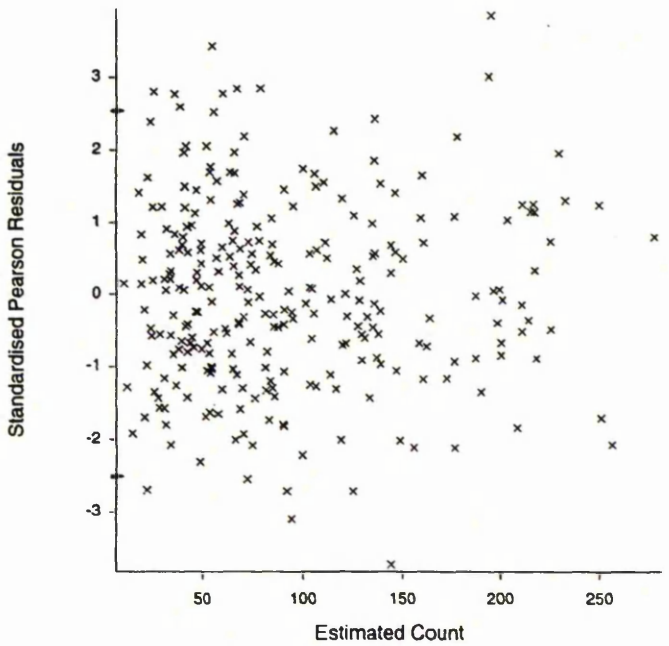
[-4.000,-3.500) 1 S
[-3.500,-3.000) 1 S
[-3.000,-2.500) 4 SSSS
[-2.500,-2.000) 10 SSSSSSSSSS
[-2.000,-1.500) 15 SSSSSSSSSSSSSSS
[-1.500,-1.000) 31 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-1.000,-0.500) 36 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.500, 0.000) 40 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.000, 0.500) 36 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.500, 1.000) 37 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[1.000, 1.500) 25 SSSSSSSSSSSSSSSSSSSSSSSSS
[1.500, 2.000) 17 SSSSSSSSSSSSSSSSS
[2.000, 2.500) 7 SSSSSSS
[2.500, 3.000) 7 SSSSSSS
[3.000, 3.500) 2 SS
[3.500, 4.000] 1 S

Mean = 0.0007 S.D.= 1.28

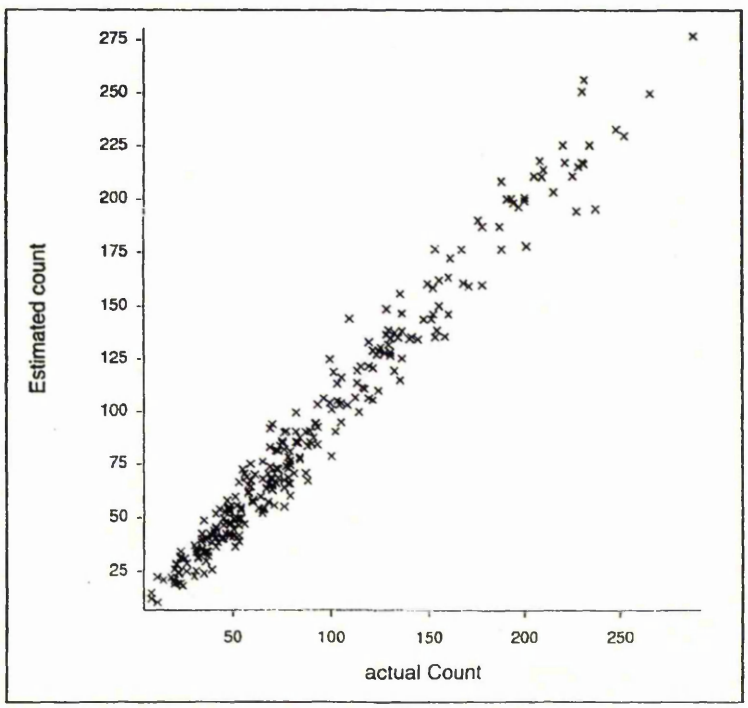
Plot 3-6-1 shows the histogram of standardised Pearson residuals of the model of table 3-6-1. Note the mean and the standard deviation of the residuals are close, respectively, to 0 and 1. Plot 3-6-2 shows the scatter plot of standardised Pearson residuals against the estimated (fitted) values. Note a few too many residuals are outside the 95% normal boundary but no clear pattern exists in residuals' variances. Plot 3-6-3 shows the scatter plot of estimated count against actual count. Plots 3-6-2 and 3-6-3 together imply that the model is fairly well fitted.

Discussion of this model is continued in section 3-9.

Plot 3-6-2 : Scatter plot of standardised Pearson residuals against estimated counts for model of table 3-6-1.



Plot 3-6-3 : Scatter plot of estimated count against actual count for model of table 3-6-1.



3-7 : A Model For Non-emergency Second Diagnosed First Admissions (admissions type 3):

In this section we fit a log linear model, with same number of parameters as previous ones, to those non-emergency first asthma admissions which belong to the patients whose second reason of hospitalisation was asthma (i.e. admissions type 3). The same set of factors, as in previous models, with same levels were used to fit to the response variable. A practical problem which exists is that we encountered many cells with a small count. We will investigate this problem when the model's goodness of fit is investigated.

Table 3-7-1 shows the log linear model which is fitted to first asthma admissions of type 3. The model includes 74 parameters and its scaled deviance is 169.4 with 196 degree of freedom. Note the model is closely fitted i.e. the scaled deviance of the model is not significantly different from its degree of freedom. Again, the model includes all main effects of the factors plus all two factor interaction except the one between year and sex, city and sex , which were not significant. The model also includes a non-significant two factor interaction term due to the factors f_year and fage_grp, i.e. even though the interaction between year of admission and age group has not been significant, it has been included in the model. The reason is that we are interested to have similar set of parameters in the models for 4 types of first admissions. Note this non significant two factor interaction means that the effect of age group on admissions type 3 has not changed from year 1984 to 1992.

Plot 3-7-1 shows the histogram of standardised Pearson residuals of the model of table 3-7-1. The mean and standard deviation of the standardised residuals are 0.004 and 0.9647 which are very close, respectively to zero and 1.

Plot 3-7-2 shows the scatter plot of standardised Pearson residuals against the estimated (fitted) count. The plot indicates a few residuals are outside the 95% normal boundary for the residuals. Nearly all these residuals are due to small counts. We mentioned before that the large sample theory which is used in estimating the residuals' variance breaks down for small count. Some pattern in residuals' variances is observed in plot 3-7-2. These pattern are due to cells with 0, 1 and even 2 counts. Note that neither those residuals which are out of 95% normal boundary nor this mentioned pattern in residuals' variance suggests that the model is not well fitted.

Plot 3-7-3 shows the scatter plot of estimated count (fitted count) against the actual count. The plot indicates that model is able to introduce a good prediction for admissions type 3. Plots 3-7-2 and 3-7-3 show that the model of table 3-7-1, even though we have large number of cells with small count, is well fitted.

Table 3-7-1 : Log Linear model fitted to first asthma admissions of type 3.

	estimate	s.e.	parameter
1	3.722	0.08050	1
2	0.006530	0.1047	F_YEAR(2)
3	0.07419	0.1045	F_YEAR(3)
4	0.5670	0.09622	F_YEAR(4)
5	0.4899	0.09766	F_YEAR(5)
6	0.2387	0.1009	F_YEAR(6)
7	0.6837	0.09446	F_YEAR(7)
8	0.7808	0.09326	F_YEAR(8)
9	0.8793	0.09273	F_YEAR(9)
10	0.5621	0.08611	F_CITY(2)
11	0.8829	0.08281	F_CITY(3)
12	-0.2603	0.1033	F_CITY(4)
13	0.5659	0.08516	F_CITY(5)
14	0.05917	0.07636	FAGE_GRP(2)

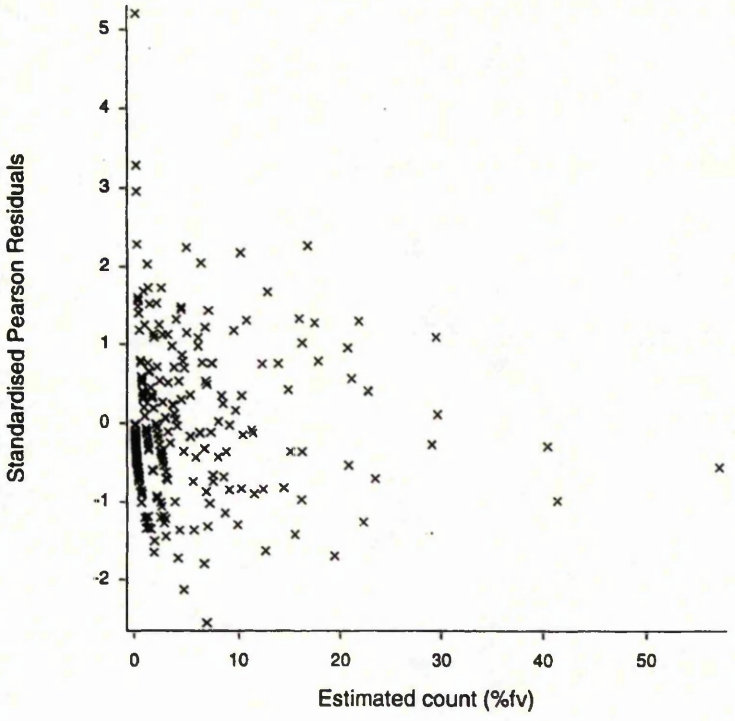
15	0.1119	0.06986	FAGE_GRP(3)
16	-0.7552	0.02874	SEX(2)
17	-0.1763	0.1052	F_YEAR(2).F_CITY(2)
18	-0.1671	0.1023	F_YEAR(2).F_CITY(3)
19	-0.3579	0.1312	F_YEAR(2).F_CITY(4)
20	-0.1057	0.1040	F_YEAR(2).F_CITY(5)
21	-0.2703	0.1068	F_YEAR(3).F_CITY(2)
22	-0.2045	0.1032	F_YEAR(3).F_CITY(3)
23	-0.2750	0.1303	F_YEAR(3).F_CITY(4)
24	-0.1343	0.1049	F_YEAR(3).F_CITY(5)
25	-0.3984	0.09939	F_YEAR(4).F_CITY(2)
26	-0.4149	0.09651	F_YEAR(4).F_CITY(3)
27	-0.3652	0.1210	F_YEAR(4).F_CITY(4)
28	-0.3533	0.09833	F_YEAR(4).F_CITY(5)
29	-0.3323	0.1018	F_YEAR(5).F_CITY(2)
30	-0.2923	0.09853	F_YEAR(5).F_CITY(3)
31	-0.09136	0.1206	F_YEAR(5).F_CITY(4)
32	-0.1295	0.09965	F_YEAR(5).F_CITY(5)
33	-0.1550	0.1034	F_YEAR(6).F_CITY(2)
34	-0.1869	0.1008	F_YEAR(6).F_CITY(3)
35	0.04939	0.1222	F_YEAR(6).F_CITY(4)
36	-0.02188	0.1018	F_YEAR(6).F_CITY(5)
37	-0.4127	0.09892	F_YEAR(7).F_CITY(2)
38	-0.2208	0.09475	F_YEAR(7).F_CITY(3)
39	-0.1676	0.1175	F_YEAR(7).F_CITY(4)
40	-0.2558	0.09710	F_YEAR(7).F_CITY(5)
41	-0.3177	0.09779	F_YEAR(8).F_CITY(2)
42	-0.2113	0.09427	F_YEAR(8).F_CITY(3)
43	-0.09156	0.1160	F_YEAR(8).F_CITY(4)
44	-0.08219	0.09565	F_YEAR(8).F_CITY(5)
45	-0.4296	0.09828	F_YEAR(9).F_CITY(2)
46	-0.1838	0.09382	F_YEAR(9).F_CITY(3)
47	-0.1542	0.1166	F_YEAR(9).F_CITY(4)
48	-0.2564	0.09643	F_YEAR(9).F_CITY(5)
49	0.05003	0.08646	F_YEAR(2).FAGE_GRP(2)
50	0.2171	0.07874	F_YEAR(2).FAGE_GRP(3)
51	0.03098	0.08580	F_YEAR(3).FAGE_GRP(2)
52	0.04438	0.07892	F_YEAR(3).FAGE_GRP(3)
53	-0.04375	0.07960	F_YEAR(4).FAGE_GRP(2)
54	-0.1812	0.07380	F_YEAR(4).FAGE_GRP(3)
55	-0.1820	0.07958	F_YEAR(5).FAGE_GRP(2)
56	-0.2275	0.07315	F_YEAR(5).FAGE_GRP(3)
57	-0.1153	0.08163	F_YEAR(6).FAGE_GRP(2)
58	-0.01400	0.07440	F_YEAR(6).FAGE_GRP(3)
59	-0.1637	0.07681	F_YEAR(7).FAGE_GRP(2)
60	-0.2973	0.07104	F_YEAR(7).FAGE_GRP(3)
61	-0.2247	0.07468	F_YEAR(8).FAGE_GRP(2)
62	-0.4258	0.06931	F_YEAR(8).FAGE_GRP(3)
63	-0.4840	0.07598	F_YEAR(9).FAGE_GRP(2)
64	-0.4528	0.06900	F_YEAR(9).FAGE_GRP(3)
65	0.3281	0.06286	F_CITY(2).FAGE_GRP(2)
66	0.4585	0.05583	F_CITY(2).FAGE_GRP(3)
67	0.3075	0.05867	F_CITY(3).FAGE_GRP(2)

68	0.2161	0.05263	F_CITY(3).FAGE_GRP(3)
69	0.4865	0.07263	F_CITY(4).FAGE_GRP(2)
70	0.1537	0.06753	F_CITY(4).FAGE_GRP(3)
71	0.5642	0.06017	F_CITY(5).FAGE_GRP(2)
72	0.4003	0.05450	F_CITY(5).FAGE_GRP(3)
73	0.1012	0.03766	FAGE_GRP(2).SEX(2)
74	1.204	0.03430	FAGE_GRP(3).SEX(2)

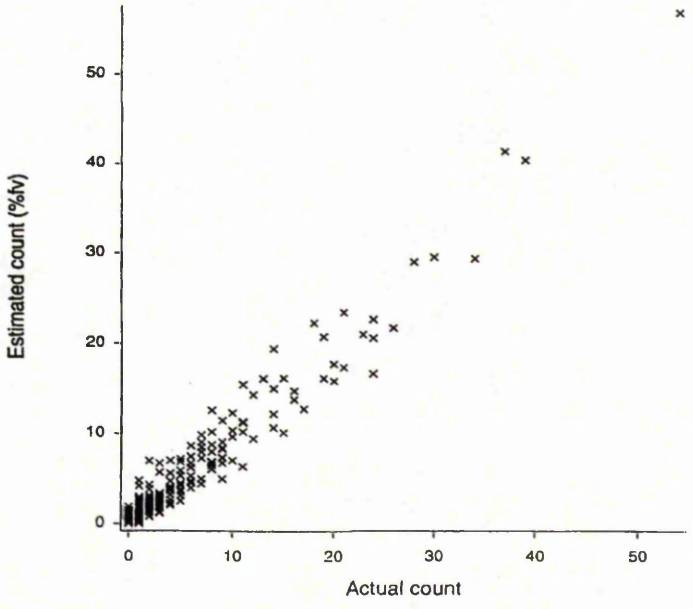
Plot 3-7-1 : Histogram of standardised Pearson residuals of model of table 3-7-1.

```
[-2.500,-2.000)   2 S
[-2.000,-1.500)   7 SSSS
[-1.500,-1.000)  24 SSSSSSSSSSSS
[-1.000,-0.500)  39 SSSSSSSSSSSSSSSSSSS
[-0.500, 0.000)  96 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.500)  30 SSSSSSSSSSSSSS
[ 0.500, 1.000)  29 SSSSSSSSSSSSSS
[ 1.000, 1.500)  24 SSSSSSSSSSSS
[ 1.500, 2.000)  11 SSSSSS
[ 2.000, 2.500)   5 SSS
[ 2.500, 3.000)   1 S
[ 3.000, 3.500)   1 S
[ 3.500, 4.000)   0
[ 4.000, 4.500)   0
[ 4.500, 5.000)   1 S
[ 5.000, 5.500]   0
                        Mean = 0.0004 S.D.= 0.9647
```

Plot 3-7-2 : Scatter plot of standardised Pearson residuals against the estimated count for model of table 3-7-1.



Plot 3-7-3 : Scatter plot of estimated count against actual count for model of table 3-7-1.



3-8 : A Model For Emergency Second Diagnosed First Admissions (admissions type 4):

Here we intend to fit a log linear model to those emergency first admissions which are due to those patients whose second reason of hospitalisation has been asthma (i.e. admissions type 4). Since this model is quite similar to the previous model we introduce the model and the its goodness of fit investigation more briefly than previous ones.

Table 3-8-1 shows the model which is fitted to admissions type 4. The model includes 74 parameters and its scaled deviance is 194.05 with 196 degree of freedom. The model is closely fitted i.e. its scaled deviance is not significantly different from its degree of freedom. The model includes all main effects and all two factor interaction terms except two factor interactions due to year and sex, city and sex.

Plot 3-8-1 shows the histogram of standardised Pearson residuals for the above model. The mean and the standard deviation of the residuals are 0.0022 and 0.976. Plot 3-8-2 shows the scatter plot of standardised Pearson residuals against the estimated (fitted) count. The plot indicates that nearly all residuals are in 95% normal boundary for residuals. It implies the model is well fitted. Plot 3-8-3 shows the scatter plot of estimated count against the actual count. This plot, once again, implies the model is well fitted.

Table 3-8-1 : Log Linear model fitted to first asthma admissions of type 4.

	estimate	s.e.	parameter
1	0.9898	0.2835	1
2	0.1887	0.3585	F_YEAR(2)
3	0.2582	0.3616	F_YEAR(3)
4	0.9847	0.3256	F_YEAR(4)
5	0.3604	0.3510	F_YEAR(5)
6	0.3206	0.3498	F_YEAR(6)
7	1.237	0.3138	F_YEAR(7)
8	1.275	0.3072	F_YEAR(8)
9	1.669	0.2966	F_YEAR(9)
10	0.4638	0.2557	F_CITY(2)
11	0.4425	0.2601	F_CITY(3)
12	-0.7848	0.3816	F_CITY(4)
13	0.2663	0.2660	F_CITY(5)
14	-0.06326	0.3139	FAGE_GRP(2)
15	1.253	0.2522	FAGE_GRP(3)
16	-0.8055	0.1006	SEX(2)
17	-0.2498	0.2832	F_YEAR(2).F_CITY(2)
18	-0.5965	0.2766	F_YEAR(2).F_CITY(3)
19	0.4219	0.4212	F_YEAR(2).F_CITY(4)
20	0.006175	0.2925	F_YEAR(2).F_CITY(5)
21	-0.2480	0.2927	F_YEAR(3).F_CITY(2)
22	-0.7098	0.2893	F_YEAR(3).F_CITY(3)
23	0.2715	0.4405	F_YEAR(3).F_CITY(4)
24	-0.1201	0.3050	F_YEAR(3).F_CITY(5)
25	-0.6723	0.2867	F_YEAR(4).F_CITY(2)
26	-0.8617	0.2767	F_YEAR(4).F_CITY(3)
27	0.5490	0.4070	F_YEAR(4).F_CITY(4)
28	-0.04283	0.2872	F_YEAR(4).F_CITY(5)
29	0.1691	0.3016	F_YEAR(5).F_CITY(2)
30	-0.2762	0.2978	F_YEAR(5).F_CITY(3)
31	0.6615	0.4391	F_YEAR(5).F_CITY(4)
32	0.3541	0.3115	F_YEAR(5).F_CITY(5)
33	0.07310	0.2984	F_YEAR(6).F_CITY(2)
34	-0.3791	0.2947	F_YEAR(6).F_CITY(3)
35	0.7041	0.4329	F_YEAR(6).F_CITY(4)
36	0.5216	0.3038	F_YEAR(6).F_CITY(5)
37	-0.08148	0.2699	F_YEAR(7).F_CITY(2)
38	-0.6206	0.2670	F_YEAR(7).F_CITY(3)
39	0.2909	0.4105	F_YEAR(7).F_CITY(4)
40	-0.1848	0.2854	F_YEAR(7).F_CITY(5)
41	0.3119	0.2604	F_YEAR(8).F_CITY(2)
42	-0.6410	0.2616	F_YEAR(8).F_CITY(3)
43	0.3519	0.4025	F_YEAR(8).F_CITY(4)
44	0.2481	0.2732	F_YEAR(8).F_CITY(5)
45	0.08226	0.2514	F_YEAR(9).F_CITY(2)
46	-0.6826	0.2492	F_YEAR(9).F_CITY(3)
47	0.2904	0.3909	F_YEAR(9).F_CITY(4)
48	0.1018	0.2635	F_YEAR(9).F_CITY(5)
49	0.2803	0.3592	F_YEAR(2).FAGE_GRP(2)

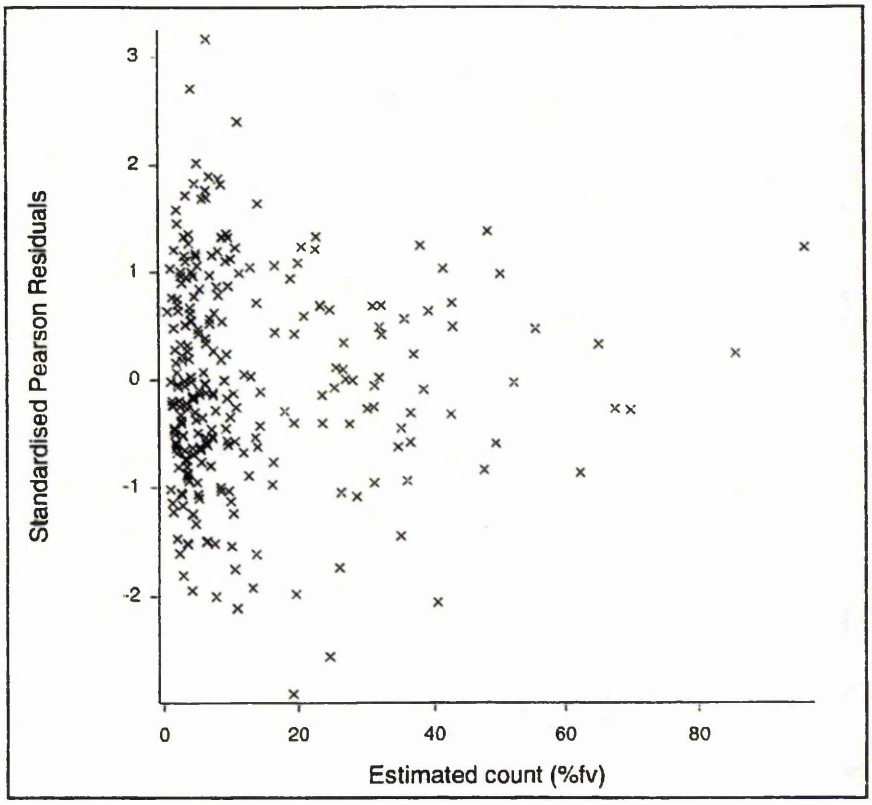
50	0.2097	0.3078	F_YEAR(2).FAGE_GRP(3)
51	-0.008823	0.3682	F_YEAR(3).FAGE_GRP(2)
52	-0.02782	0.3096	F_YEAR(3).FAGE_GRP(3)
53	-0.3938	0.3309	F_YEAR(4).FAGE_GRP(2)
54	-0.6015	0.2748	F_YEAR(4).FAGE_GRP(3)
55	-0.2792	0.3392	F_YEAR(5).FAGE_GRP(2)
56	-0.4546	0.2830	F_YEAR(5).FAGE_GRP(3)
57	-0.3113	0.3425	F_YEAR(6).FAGE_GRP(2)
58	-0.2987	0.2836	F_YEAR(6).FAGE_GRP(3)
59	-0.5389	0.3143	F_YEAR(7).FAGE_GRP(2)
60	-0.8159	0.2603	F_YEAR(7).FAGE_GRP(3)
61	-0.5382	0.3030	F_YEAR(8).FAGE_GRP(2)
62	-0.7136	0.2511	F_YEAR(8).FAGE_GRP(3)
63	-1.034	0.3032	F_YEAR(9).FAGE_GRP(2)
64	-0.7633	0.2445	F_YEAR(9).FAGE_GRP(3)
65	0.5252	0.2168	F_CITY(2).FAGE_GRP(2)
66	0.5518	0.1579	F_CITY(2).FAGE_GRP(3)
67	0.9210	0.2332	F_CITY(3).FAGE_GRP(2)
68	0.9533	0.1772	F_CITY(3).FAGE_GRP(3)
69	0.5750	0.2567	F_CITY(4).FAGE_GRP(2)
70	-0.3525	0.2035	F_CITY(4).FAGE_GRP(3)
71	0.6277	0.2177	F_CITY(5).FAGE_GRP(2)
72	0.3816	0.1611	F_CITY(5).FAGE_GRP(3)
73	0.1034	0.1379	FAGE_GRP(2).SEX(2)
74	1.121	0.1085	FAGE_GRP(3).SEX(2)

Plot 3-8-1 : Histogram of standardised Pearson residuals of model of table 3-8-1.

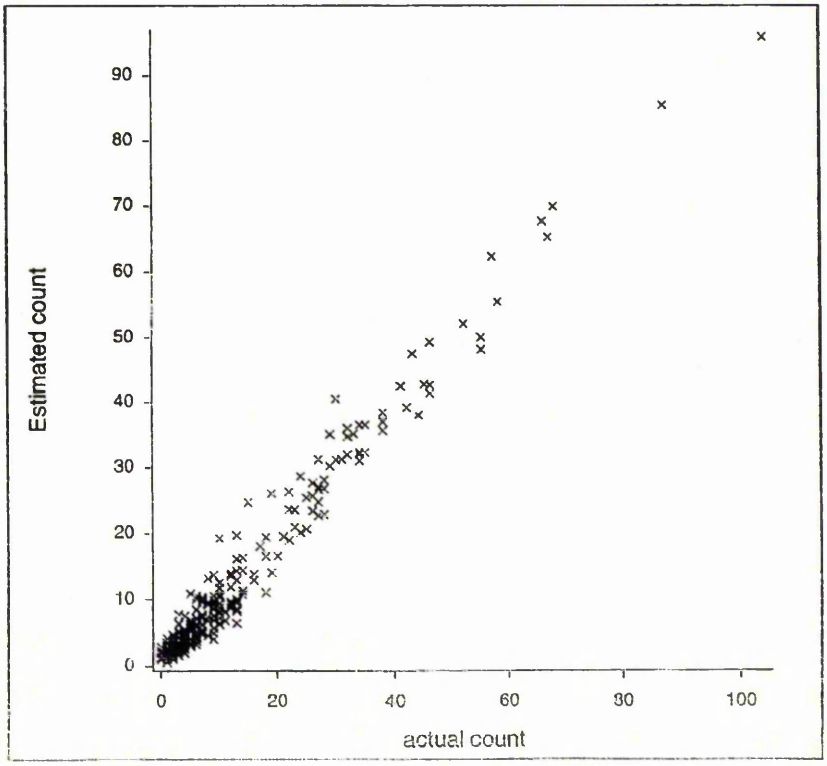
[-3.200,-2.800) 1 S
[-2.800,-2.400) 1 S
[-2.400,-2.000) 3 SSS
[-2.000,-1.600) 8 SSSSSSSS
[-1.600,-1.200) 13 SSSSSSSSSSSSS
[-1.200,-0.800) 26 SSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.800,-0.400) 47 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.400, 0.000) 51 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.000, 0.400) 26 SSSSSSSSSSSSSSSSSSSSSSSSSS
[0.400, 0.800) 35 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.800, 1.200) 27 SSSSSSSSSSSSSSSSSSSSSSSSSSS
[1.200, 1.600) 18 SSSSSSSSSSSSSSSSSS
[1.600, 2.000) 10 SSSSSSSSSS
[2.000, 2.400) 1 S
[2.400, 2.800) 2 SS
[2.800, 3.200] 1 S

Mean = 0.0022 S.D.= 0.976

Plot 3-8-2 : Scatter plot of standardised Pearson residuals against estimated count for model of table 3-8-1.



Plot 3-8-3 : Scatter plot of estimated count against actual count for model of table 3-8-1.



3-9 : Comparisons and Interpretations of Fitted Models to Different Types of First Admissions :

So far, in sections 3-5 to 3-8, four log linear models were fitted to 4 types of first admissions. Recall that these types of first admissions are the result of counting first admissions in different combination of two factors admission type (non-emergency or emergency) and diagnosis type (asthma as the first or second reason of hospitalisation). It was shown that each of these four models was fairly well fitted to the related number of first admissions. We are therefore able to use these models to discuss the relation between the factors and the response variables and also to investigate how the factors affect the different types of first admissions. This helps us to get some ideas as to the pattern of first admissions of each type. This helps to discover for which type, or of what time, and in which age groups or sexes the increase in number of first admissions, if any, have occurred. We carry out these aims by presenting some simple plots for each type of first admissions.

The plots which we are going to produce to show different aspects of the pattern of a given type of first admissions are :

1- Scatter plot of estimated number of first admissions against age group, showing the age profile in each city, for fixed year and sex. These plots stand for the interaction between two factors age group and city. In looking at these plots, we are interested only in $(\alpha\beta)_{ij}$ interaction, not the main effects as explained later. There are 18 such plots for each model due to 9 levels of factor year multiplied by 2 levels of

factor sex. We claim, as long as we are only interested in investigating the interaction between age group and city i.e. in $(\alpha\beta)_{ij}$, one single plot could stand for all these plots. Therefore we will produce one plot for each model to illustrate the interaction $(\alpha\beta)_{ij}$ in each model. Later we show how all those 18 plots show similar $(\alpha\beta)_{ij}$. Note in none of these 18 plots are we interested in main effects of either age group or city. The reason is that any difference in main effects is simply due to difference in population size in different age groups or different cities. We decided to prepare this single plot for male patients in year 1984.

2- Scatter plots of estimated number of first admissions against year of admissions, showing the pattern of changes in each city, for fixed age group and sex. These are 6 plots (3*2) and stand for interaction between two factors year and city. Such plots show same $(\beta\gamma)_{jk}$. Unlike the situation for the plots just discussed in 1, we are interested in comparing years directly, and not only in their interaction with city. The comparison of years depends of course on city (as seen in any of the 6 plots), but also on age group, due to the $(\alpha\gamma)_{ik}$ interaction. Therefore we decided to produce the 3 plots for males, of various ages. Note that the models have no year*sex interaction, so nothing further would be learnt from the 3 female plots.

3- Scatter plots of estimated number of first admissions against year of admissions, showing the pattern of changes in each age group, for fixed city and sex. These are 10 plots (5*2) and stand for the interaction between year and age group. All these plots show same $(\alpha\gamma)_{ik}$ which is the interaction between age group and year. Once again, we are interested in comparing years directly while not interested in

direct comparison of age groups. We decided to show the 5 plots for males, in various cities, since the comparison of years depends on both age groups and cities.

4- Scatter plots of estimated number of first admissions against age group, showing the age profile for each sex, for fixed year and city. These are 45 (9*5) plots and any one shows the interaction between age group and sex. Direct comparison of sexes is of interest, but depends neither on city nor year, since neither of these two factors has interaction with sex. It implies any of these 45 plots could stand for the interaction between age group and sex. We decided to use Glasgow 1984 admissions.

Note we need 1+3+5+1=10 plots for each model to illustrate the pattern of first admission of that type.

So far, for example in (1), we claimed all 18 mentioned plots showed same $(\alpha\beta)_{ij}$ (interaction between age group and city) and therefore we decided to produce only one plot, instead of 18, to show the interaction between these two factors. Here we prepare two of these plots and will show the similar $(\alpha\beta)_{ij}$ which exists in both plots. Plots 3-9-1 and 3-9-2 show the number of first admissions of type 2 in different age groups and different cities for males, respectively, in years 1984 and 1992. Let's see what terms are included in each plot. First, once again, we write the model which is fitted to data,

$$\text{Log } \mu_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\alpha\delta)_{il} + (\beta\gamma)_{jk}$$

where,

i= N_agemar

j= f_city

k= f_year

l= sex,

According to above model, plots 3-9-1 and 3-9-2 show respectively the exponentials of

$$[\mu+\gamma_{1984}+\delta_{male}] + [\alpha_i+(\alpha\gamma)_{i'1984'}+(\alpha\delta)_{i'male'}] + [\beta_j+(\beta\gamma)_{j'1984'}] + (\alpha\beta)_{ij}$$

and,

$$[\mu+\gamma_{1992}+\delta_{male}] + [\alpha_i+(\alpha\gamma)_{i'1992'}+(\alpha\delta)_{i'male'}] + [\beta_j+(\beta\gamma)_{j'1992'}] + (\alpha\beta)_{ij}$$

Note even though the second and third brackets are different in two plots, but as far as we are looking at interaction between age group and city, both plots includes the term $(\alpha\beta)_{ij}$ only. It implies as far as we are interested in illustrating the interaction between these two factors, we could use only one of these plots.

First we use first group of plots which stand for interaction between age group and city. There were 18 such plots for each model but, since we claimed one single plot is enough to illustrate the mentioned interaction for each model, therefore 4 plots are needed to show the interaction between age group and city in all four models. These are plots 3-9-3 to 3-9-6, respectively, for first admission of type 1 to first admission of type 4. They have been produced for males in year 1984. These plots indicate that the interaction between age group and city is similar in first admissions of type 1, 3 and 4 i.e. number of first admissions of these types has increased equally sharply in different cities as the age group increased. There is an exception for Aberdeen (code 1) for admissions of type 1 and 3 which indicates first admissions of type 1 (non-emergency first diagnosed) and type 3 (non-emergency second diagnosed) have not increased as sharply as they have increased in other cities. Plot 3-9-4 shows the mentioned interaction (age group*city) for first admission of type 2 (emergency first diagnosed asthma) is different from other types. This plot indicates, the pooled city (Dundee, Kilmarnock and Paisley, code 5) has the sharpest increase (among cities) in this type of first admission from age group 1 to age group 2. The sharpness of increase (of this type of admissions) from

age group 1 to 2, in cities Glasgow (code 3), Edinburgh (code 2) and Motherwell (code 4) are almost similar while rate of increase in Aberdeen (from age group 1 to 2) is almost zero. From age group 2 to 3, we see a rate of decrease in this type of admission for cities Glasgow, Motherwell and pooled cities and a rate of increase for Edinburgh and Aberdeen which is very small for Aberdeen. Note the age profile is very different in Edinburgh. These results may reflect different age-distributions in population of different cities.

We remind the reader that study of interactions comprises ratios of ratios, such as (for babies and children in Glasgow and pooled city)

$$(\mu_{13kl} / \mu_{15kl}) / (\mu_{23kl} / \mu_{25kl}).$$

Form plot 3-9-1 (k=1, l=1) we have,

$$(100 / 73) / (144 / 135) = 1.28$$

From plot 3-9-2 (k=9, l=1) we have,

$$(200 / 135) / (179 / 155) = 1.28$$

Next we discuss the interaction between city and year. We have showed that we need 3 plots to illustrate how yearly changes for each model depend on both city and age group. The reason was we were interested in yearly changes of first admission and changing the age group would change these yearly changes. Note we need 12 plots (3 for each model) for all 4 models which are fitted to 4 types of first admission. These are plots 3-9-7 to 3-9-18.

Plots 3-9-7 to 3-9-9 show the number of first admission of type 1 (non-emergency, first diagnosed) in different cities, showing the pattern of changes over years, for male patients for, respectively, babies, children and adults (3 levels of age group).These plots stand for interaction between city and year in each age group for admission type 1. Plots 3-9-10 to 3-9-12, 3-9-13 to 3-9-15 and 3-9-16 to 3-9-18 are similar plots as 3-9-7 to 3-9-9 which have been produced for admissions type 2, 3 and 4. First we discuss about each group of

these plots to investigate the interaction (between city and year) and the yearly changes in each type of first admission. Then we compare these plots (one from each type of admission) with each other to discuss the differences in pattern of first admission in different type of admission.

Plots 3-9-7 to 3-9-9 indicate, among all cities, there is only one apparent increase and one decrease in number of non-emergency first diagnosed admissions (type 1). The increase is due to pooled city (code 5) in babies age group and the decrease is due to Glasgow in adults age group. We used the word "apparent" to remind the reader that there were only a few babies admitted as type 1, therefore the increase that is reported here, is based on small count i.e. is not very important. The number of admissions in adults age group is fairly large, suggesting this decrease is important. This type of admission has not changed, from year 1984 to year 1992, in other cities. There are two more points which are worth mentioning. First, in children's age group, this type of admission has decreased in all cities in year 1988. Actually there is a trough in the pattern of admission in year 1988 in all cities. Once again, since the admissions of this type in children's age group are small therefore the mentioned decrease is not important.

Plots 3-9-10 to 3-9-12, which are due to emergency first diagnosed admissions, the most common type of admissions in our data, indicate that in no age group shows very much important interaction between city and year. These plots show the most important increases, in admissions of this type, have happened in babies age group. In this age group, the admissions have increased in all cities and the important part of increase has happened after year 1989. In some cities like Glasgow and Aberdeen the admissions were doubled from year 1984 to year 1992. Plot 3-9-11 and 3-9-12 show that in children and adult age groups, first admissions have increased in all cities except in Edinburgh.

Plots 3-9-13 to 3-9-15, which are due to non-emergency second diagnosed admissions, show that admissions of this type have increased on period of study, only in Edinburgh and pooled city. In both these cities the admissions in year 1992 are four times the admissions in 1984 and the increase has begun around year 1988 and 1989. Note the increases in all cities, which are shown by plot 3-9-13 (due to babies) are based on too few admissions therefore no comment could be made on them.

Plots 3-9-16 to 3-9-18, which are due to emergency second diagnosed admissions, show this type of admission has increased almost in all cities. The most dramatic increases have happened in Edinburgh and pooled city. The increases over years in babies age group are more consistent than two other age group.

Plots 3-9-7 to 3-9-18 indicate the most dramatic increase in first admissions, over period of study, is due to increase in all types of admission in babies age group i.e. in almost all cities, all types of admission have increased in babies age group. It is not the case for other age groups. In children age group and in some types of admissions, admissions have increased in some cities while it has remained constant in some other cities. In adults, even though some increase has happened in some cities like Edinburgh, Glasgow and pooled city but in Glasgow the admissions of type 1 have decreased dramatically. A very important point is that, in most cases, whenever the increase has occurred it has occurred around the year 1989.

Each of plots 3-9-19 to 3-9-38 shows the estimated number of first admissions against year of admissions, showing the pattern of changes in each age group, in a particular city for male patients. Each group of 5 of these plots belong to a particular type of admission. These plots stand for the interaction between age group and year of admission.

The first 5 of above mentioned plots (plots 3-9-19 to 3-9-23) are due to admission type 1(non-emergency, first diagnosed). These 5 plots indicate while in none of the cities have admissions of this type increased over years 1984 to 1992 in babies age group, this type of admission, in children and adults age group, has increased in Aberdeen, but it decreased in rest of the cities. It implies in almost all cities (all cities except Aberdeen) non-emergency first diagnosed admissions have decreased, in children and adults age group, over years 1984 to 1992.

Plots 3-9-24 to 3-9-28, which are due to admissions type 2, stand for the interaction between age group and year of admissions in each city. These plots indicate that, in all cities and all age groups admissions of type 2 have increased. There is one exception for Edinburgh and that is, this type of admission has not increased in children and adults age group. Always the most dramatic increase has been due to babies age group.

Plots 3-9-29 to 3-9-33 are due to admission type 3 (non-emergency, second diagnosed) and indicate that admissions of this type, over years 1984 to 1992, have remained constant in babies age group in all cities. This type of admissions in children and adults age groups in cities Edinburgh, Motherwell and pooled city have increased in period of study. In other cities (Aberdeen and Glasgow) it remained constant.

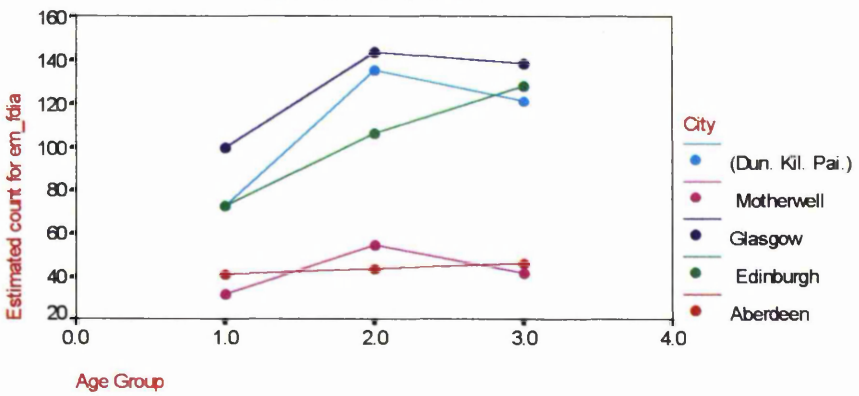
Plots 3-9-34 to 3-9-38 show the admissions type 4 in different years and age groups in each city for male patients. The plots show admissions of type 4 have increased in all age groups from year 1984 to 1992, in all cities except for children age group in Aberdeen, Edinburgh and Glasgow.

Finally we examined the interaction between age and sex. Plots 3-9-39 to 3-9-42 show the estimated number of first admissions in different sexes and different age groups, for year 1984 in Glasgow. All plots suggest a very strong

interaction between sex and age group. This interaction is stronger between age group 2 and 3 (between children and adults). For instance, for type 2 admissions, there are about twice as many boys as girls (age group 2), but only two-thirds as many men as women (age group 3). The pattern of interaction between age group and sex is very similar for all types of first admissions. According to these plots, as the age group increases the number of first admissions in both sexes increase except for admissions type 2 for males. For this group of patients, number of first admissions in age group 2 (children) are more than first admissions in age group 1 (babies) but it is less than number of first admissions in adults.

Plot 3-9-1 : Plot of estimated count for em_fdia (first ad. of type 2) in different cities against age groups.

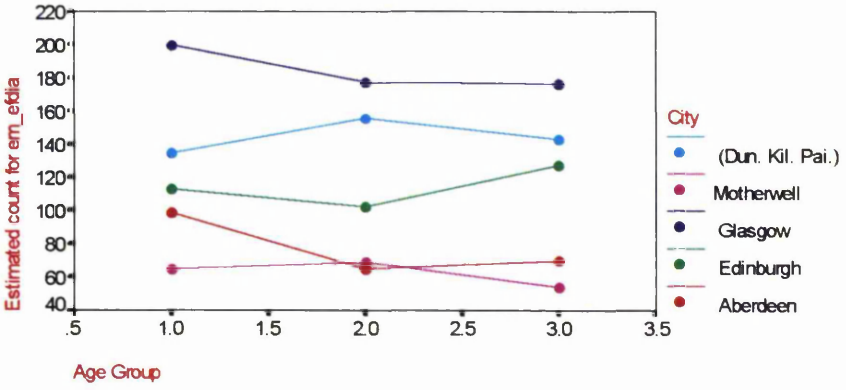
For Year 1984, Males.



Plot 3-9-2 : Plot of estimated count for em_fdia (first ad. of type 2)

in different cities against age groups.

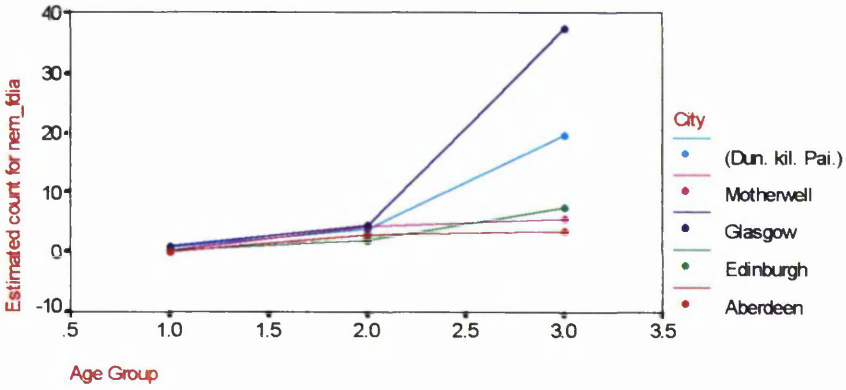
For Year 1992, Males.



Plot 3-9-3 : Plot of estimated count for nem_fdia(first ad. of type 1)

in different cities against age groups.

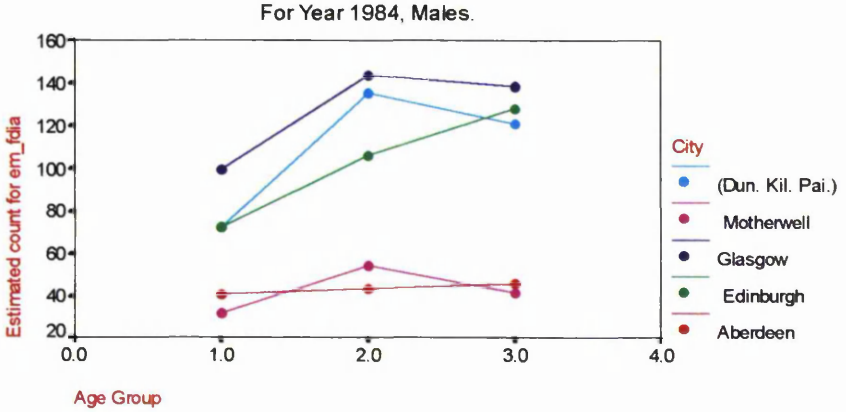
For Year 1984, Males.



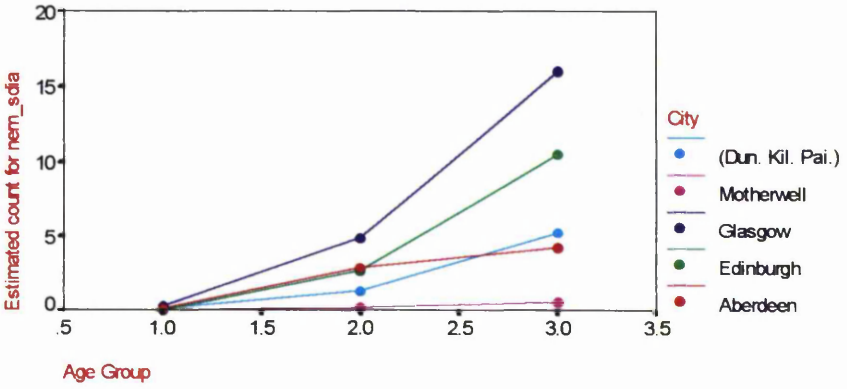
Plot 3-9-4 : Plot of estimated count for em_fdia (first ad. of type 2)

in different cities against age groups.

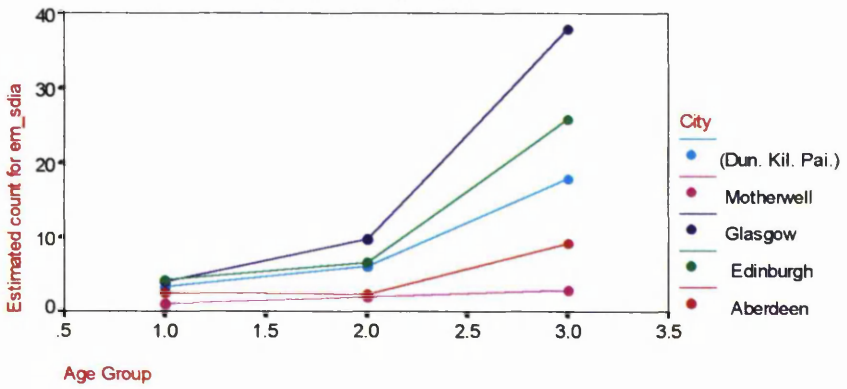
For Year 1984, Males.



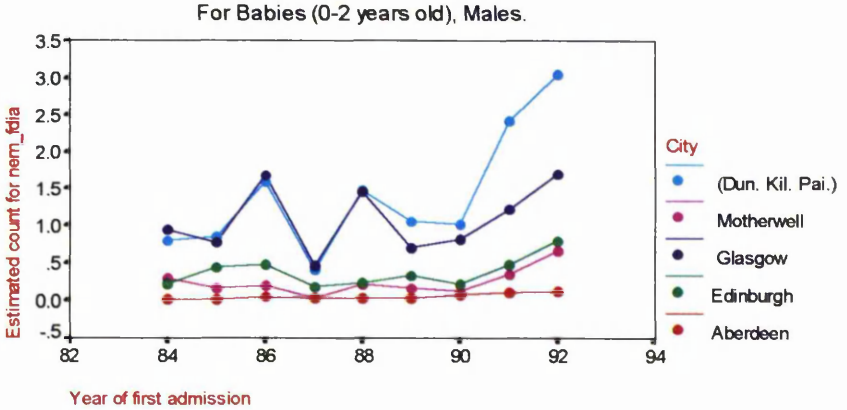
Plot 3-9-5 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different cities against age groups.
For Year 1984, Males.



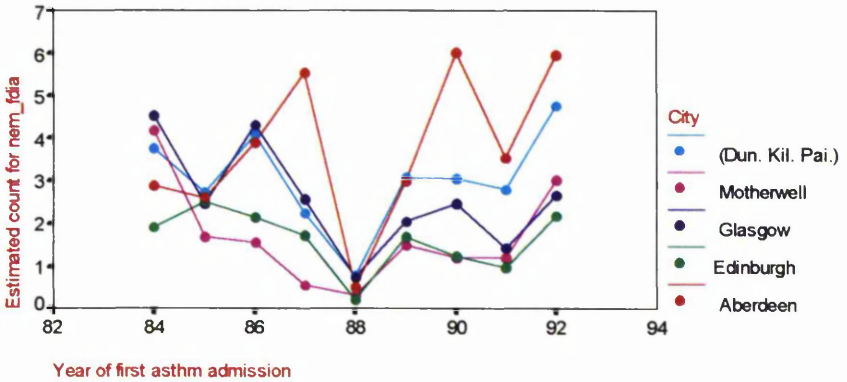
Plot 3-9-6 : Plot of estimated count for em_sdia (first ad. of type 4)
in different cities against age groups.
For Year 1984, Males.



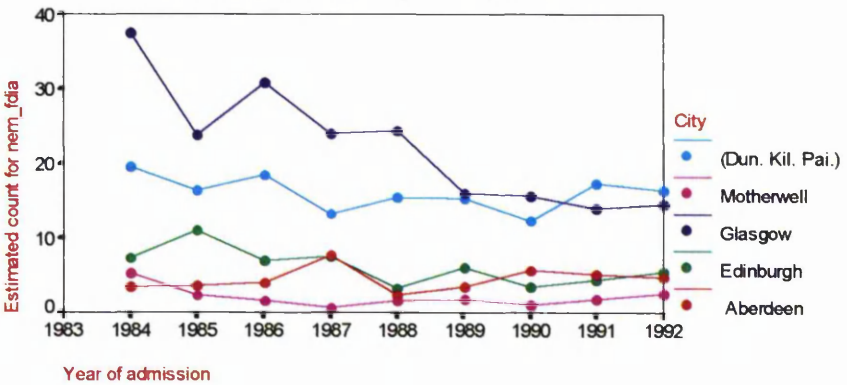
Plot 3-9-7 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different cities over year 1984 to 1992.
For Babies (0-2 years old), Males.



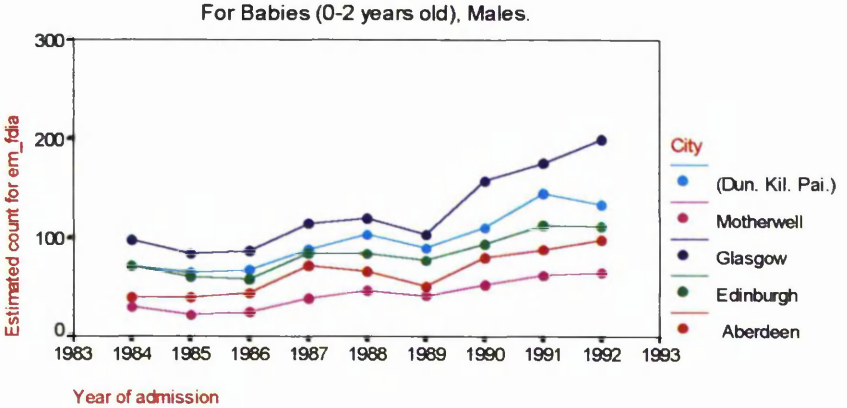
Plot 3-9-8 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different cities over year 1984 to 1992.
For Children (3-14 years old), Males.



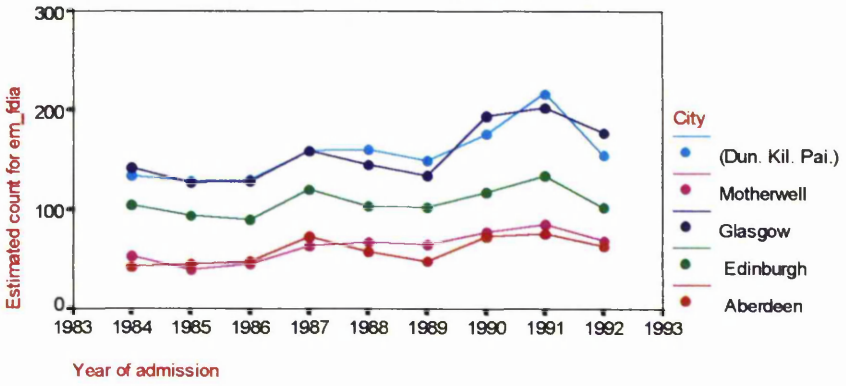
Plot 3-9-9 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different cities over year 1984 to 1992.
For adults(More than 14 years old), Males.



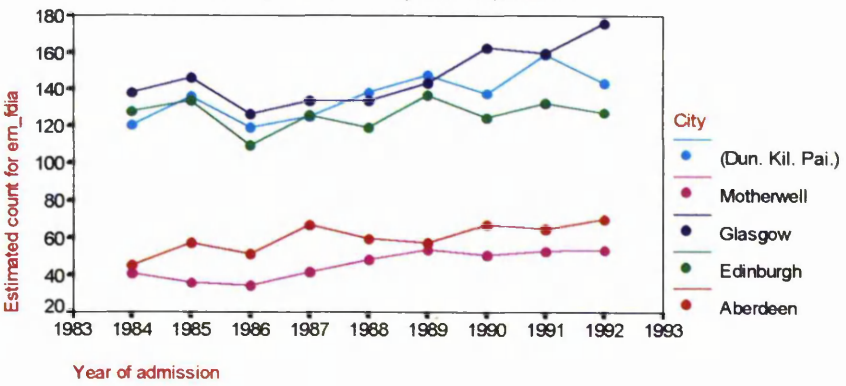
Plot 3-9-10 : Plot of estimated count for em_fdia (first ad. of type 2)
in different cities over year 1984 to 1992.
For Babies (0-2 years old), Males.



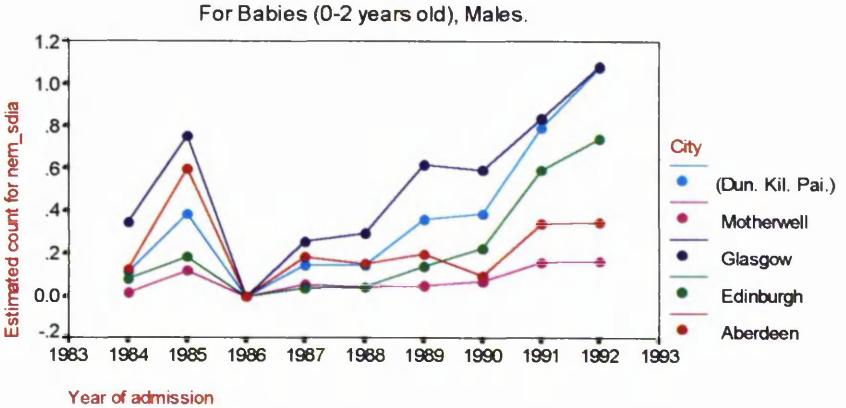
Plot 3-9-11 : Plot of estimated count for em_fdia (first ad. of type 2)
in different cities over year 1984 to 1992.
For children (3-14 years old), Males.



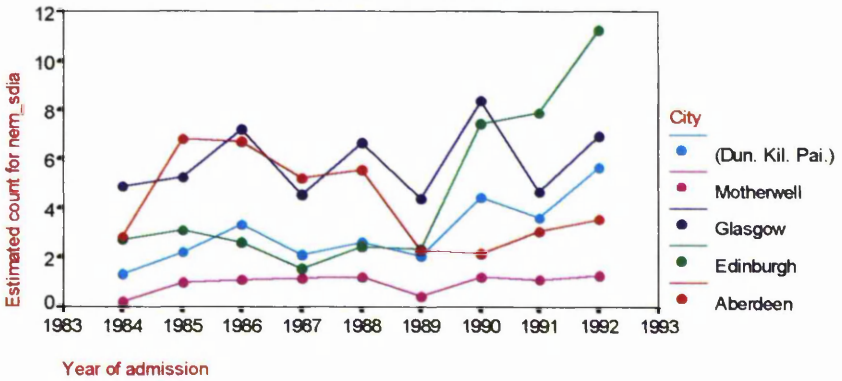
Plot 3-9-12 : Plot of estimated count for em_fdia (first ad. of type 2)
in different cities over year 1984 to 1992.
For adults (More than 14 years old), Males.



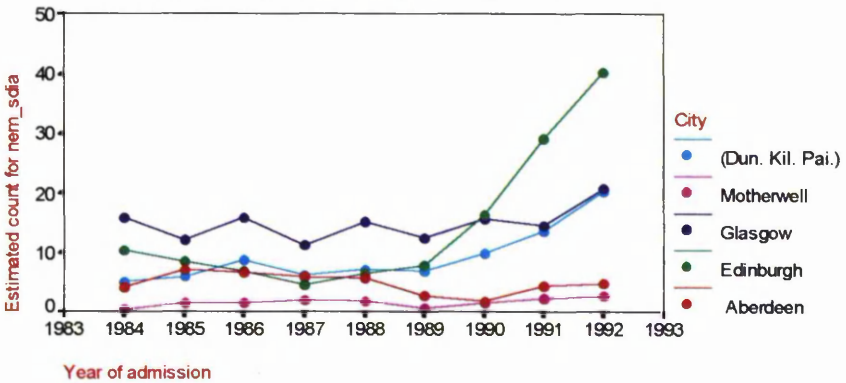
Plot 3-9-13 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different cities over year 1984 to 1992.
For Babies (0-2 years old), Males.



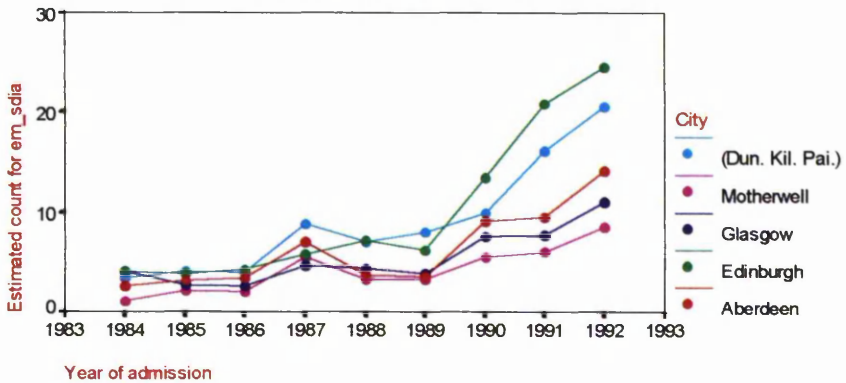
Plot 3-9-14 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different cities over year 1984 to 1992.
For children (3-14 years old), Males.



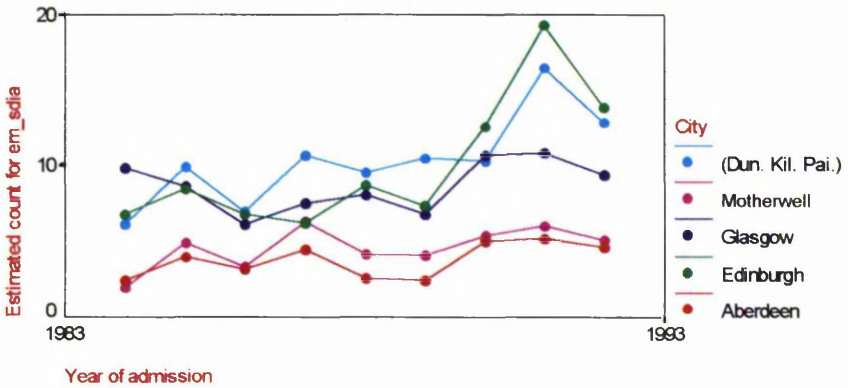
Plot 3-9-15 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different cities over year 1984 to 1992.
For adults (More than 14 years old), Males.



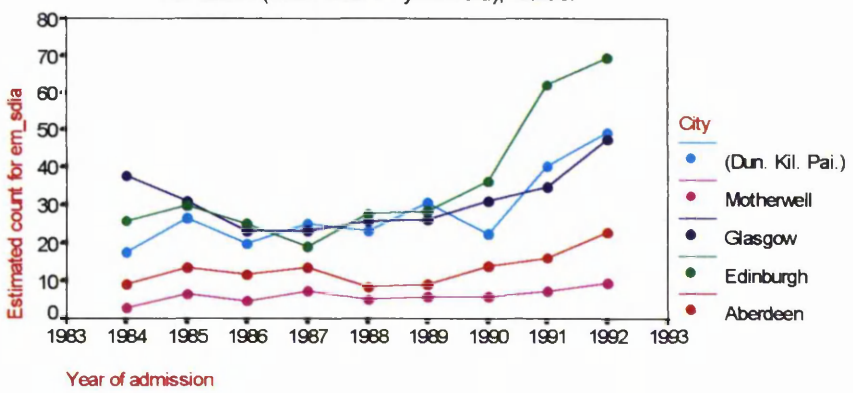
Plot 3-9-16 : Plot of estimated count for em_sdia (first ad. of type 4)
in different cities over year 1984 to 1992.
For Babies (0-2 years old), Males.



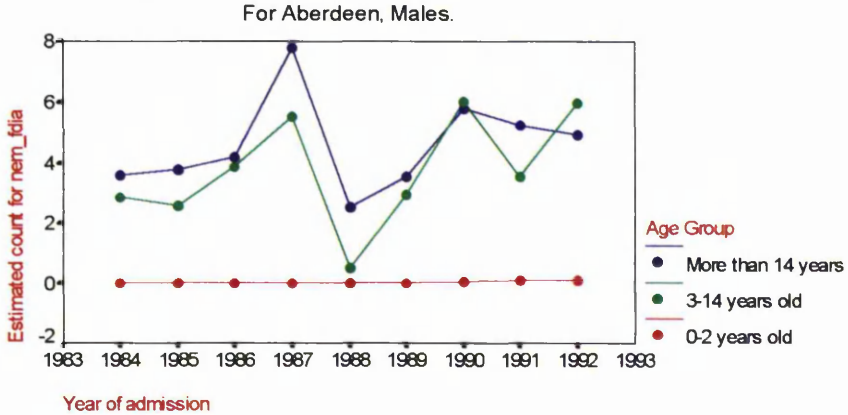
Plot 3-9-17 : Plot of estimated count for em_sdia (first ad. of type 4)
in different cities over year 1984 to 1992.
For children (3-6 years old), Males.



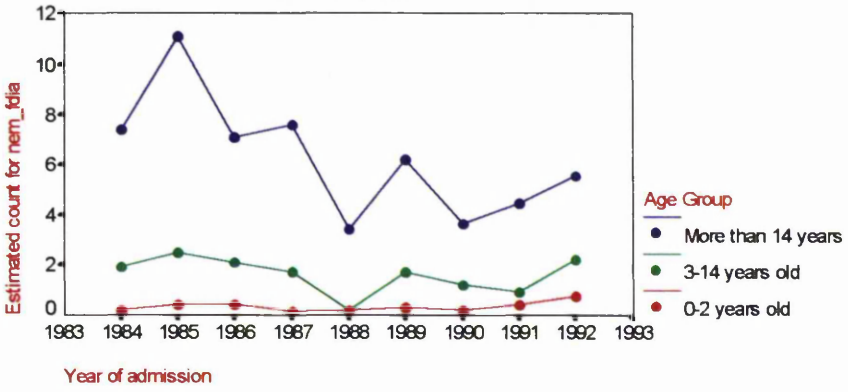
Plot 3-9-18 : Plot of estimated count for em_sdia (first ad. of type 4)
in different cities over year 1984 to 1992.
For adults (more than 14 years old), Males.



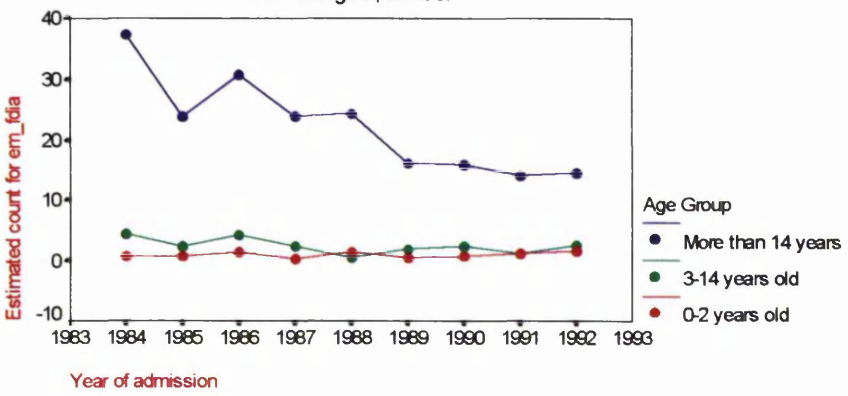
Plot 3-9-19 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different age groups over year 1984 to 1992.
For Aberdeen, Males.



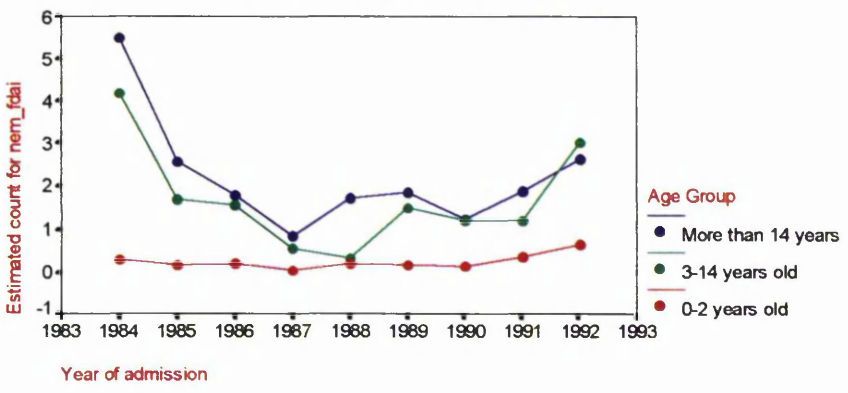
Plot 3-9-20 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different age groups over year 1984 to 1992.
For Edinburgh, Males.



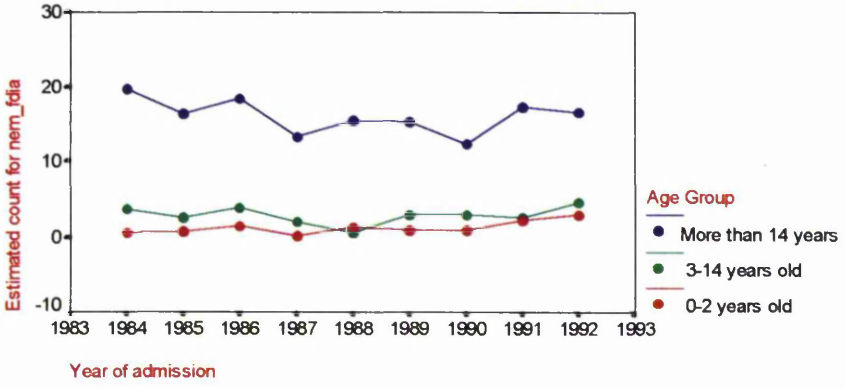
Plot 3-9-21 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different age groups over years 1984 to 1992.
For Glasgow, Males.



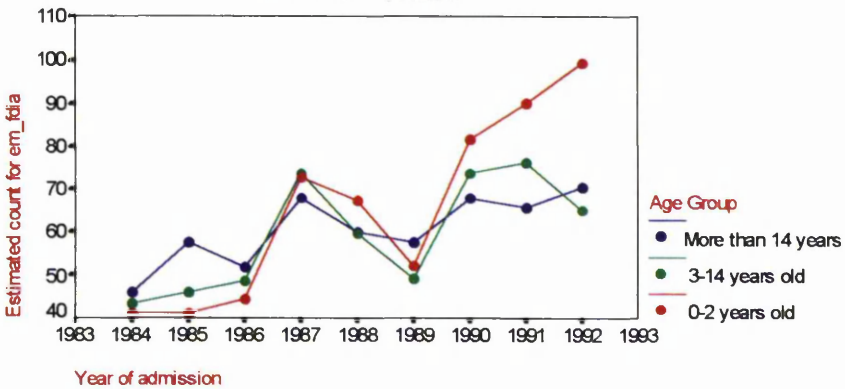
Plot 3-9-22 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different age groups over year 1984 to 1992.
For Motherwell, Males.



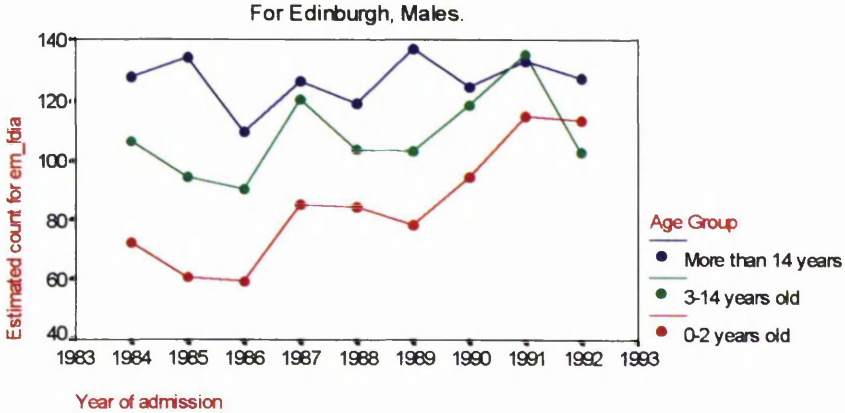
Plot 3-9-23 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different age groups over year 1984 to 1992.
For pooled cities (Dun. Kil. pai.), Males.



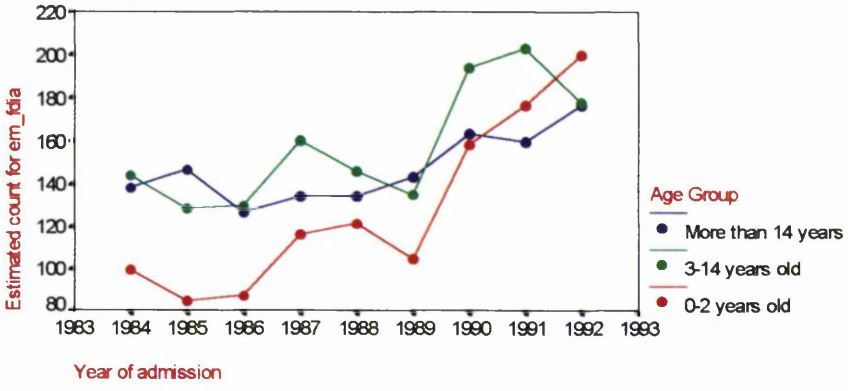
Plot 3-9-24 : Plot of estimated count for em_fdia (first ad. of type 2)
in different age groups over years 1984 to 1992.
For Aberdeen, Males.



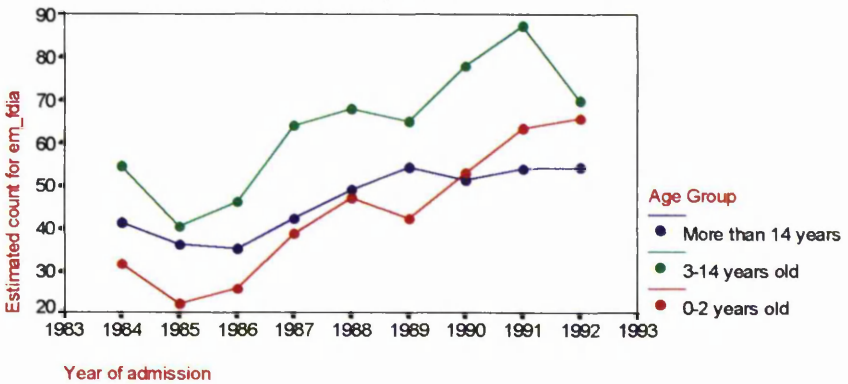
Plot 3-9-25 : Plot of estimated count for em_fdia (first ad. of type 2)
in different age groups over years 1984 to 1992.
For Edinburgh, Males.



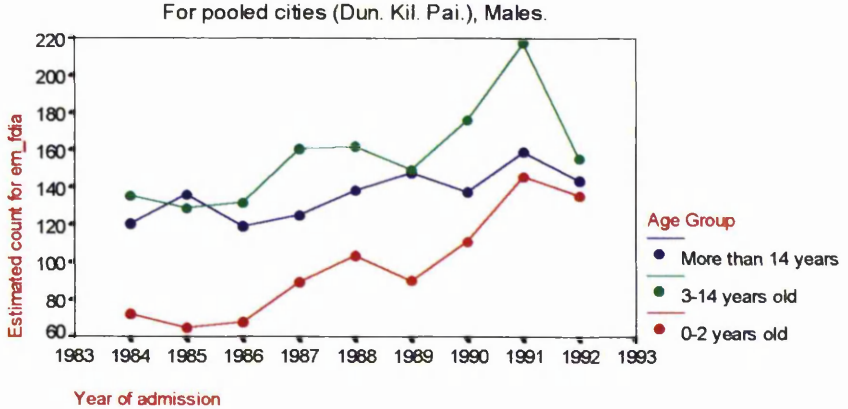
Plot 3-9-26 : Plot of estimated count for em_fdia (first ad. of type 2)
in different age groups over years 1984 to 1992.
For Glasgow, Males.



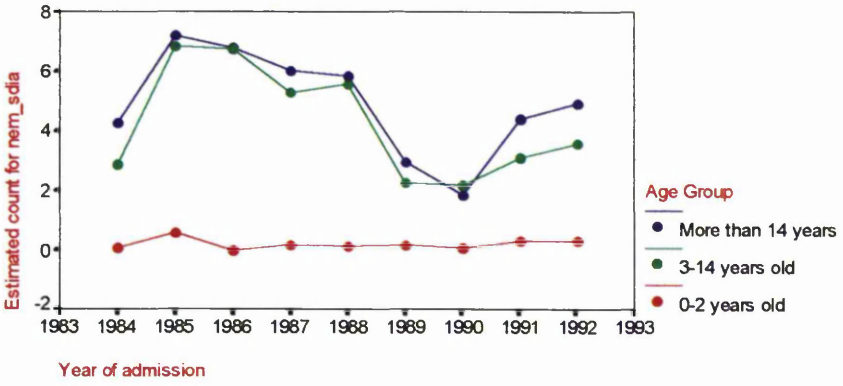
Plot 3-9-27 : Plot of estimated count for em_fdia (first ad. of type 2)
in different age groups over years 1984 to 1992.
For Motherwell, Males.



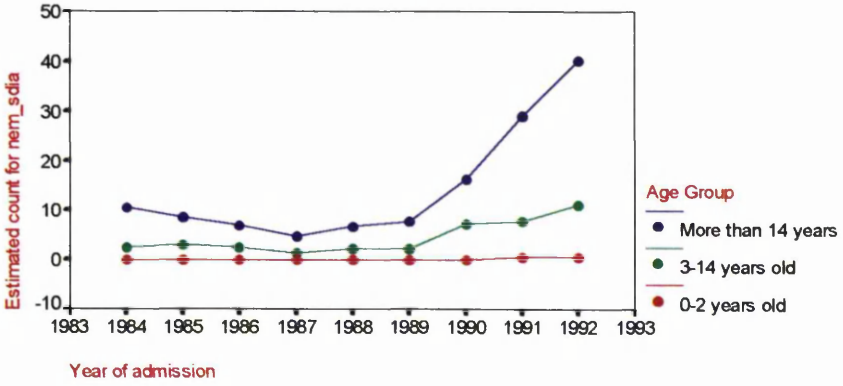
Plot 3-9-28 : Plot of estimated count for em_fdia (first ad. of type 2)
in different age groups over years 1984 to 1992.
For pooled cities (Dun. Kil. Pai.), Males.



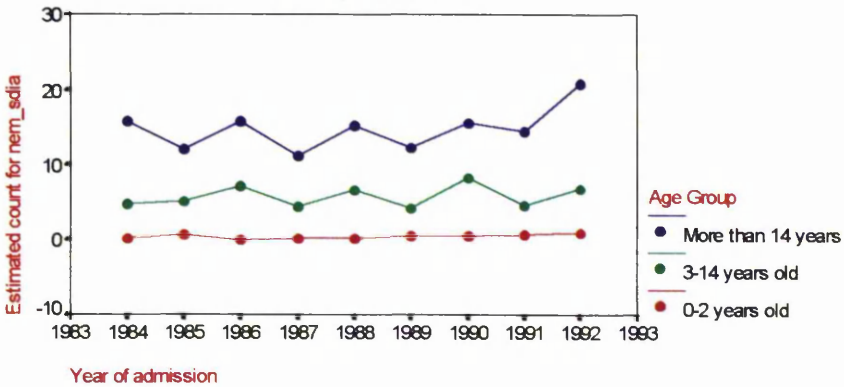
Plot 3-9-29 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different age groups over years 1984 to 1992.
For Aberdeen, Males.



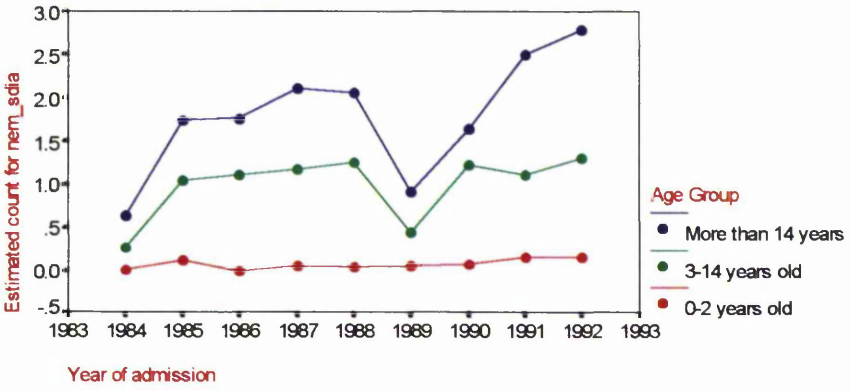
Plot 3-9-30 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different age groups over years 1984 to 1992.
For Edinburgh, Males.



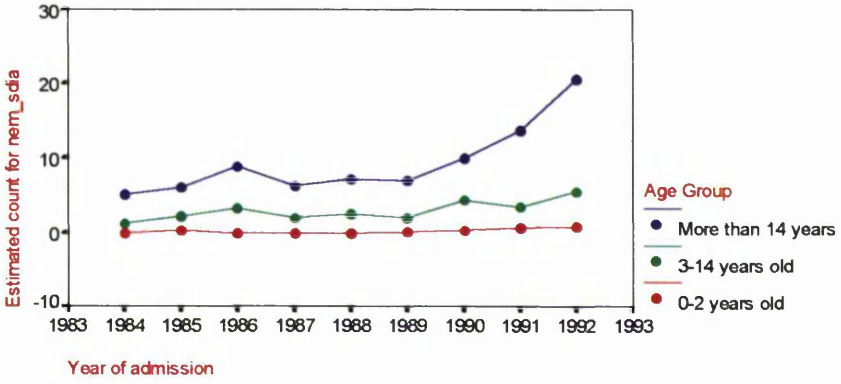
Plot 3-9-31 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different age groups over years 1984 to 1992.
For Glasgow, Males.



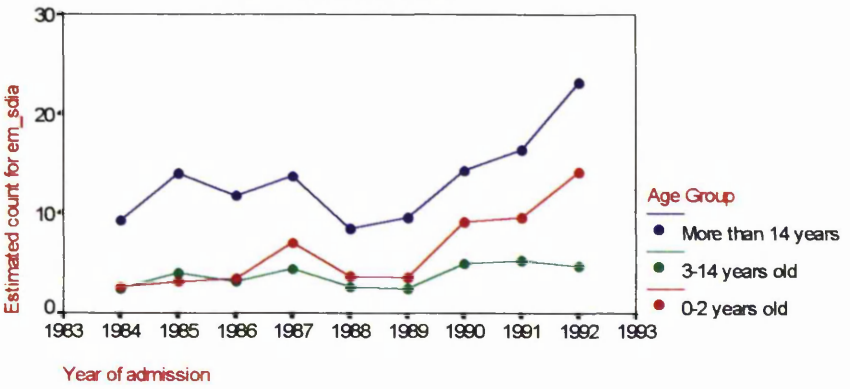
Plot 3-9-32 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different age groups over years 1984 to 1992.
For Motherwell, Males.



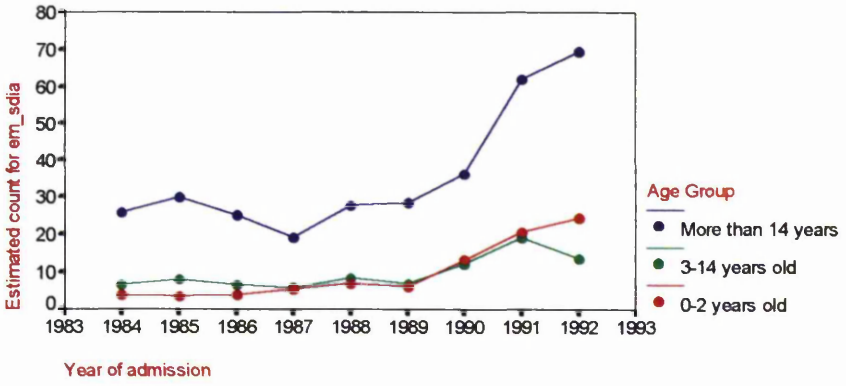
Plot 3-9-33 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different age groups over years 1984 to 1992.
For pooled cities (Dun. Kil. Pai.), Males.



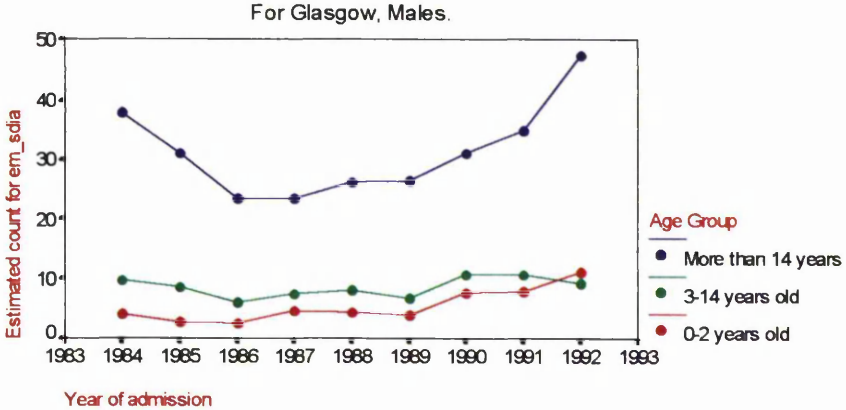
Plot 3-9-34 : Plot of estimated count for em_sdia (first ad. of type 4)
in different age groups over years 1984 to 1992.
For Aberdeen, Males.



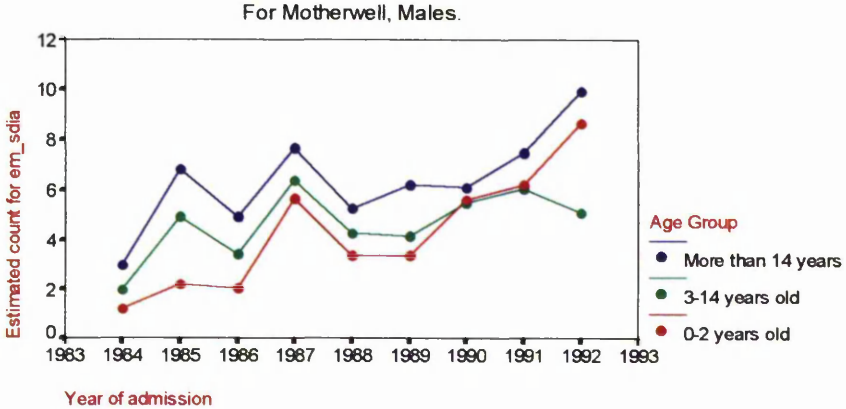
Plot 3-9-35 : Plot of estimated count for em_sdia (first ad. of type 4)
in different age groups over years 1984 to 1992.
For Edinburgh, Males.



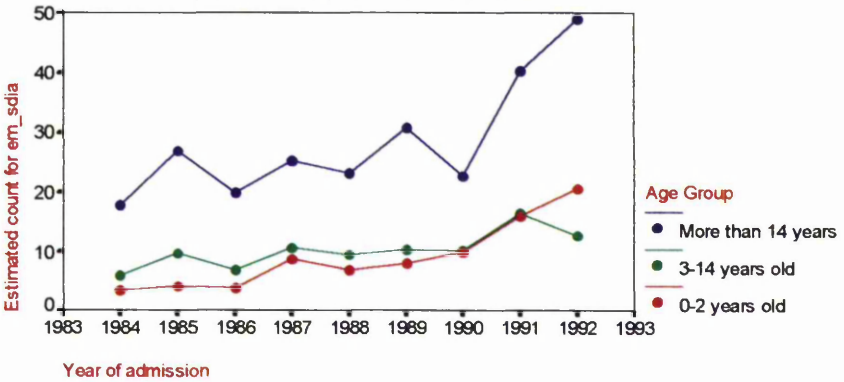
Plot 3-9-36 : Plot of estimated count for em_sdia (first ad. of type 4)
in different age groups over years 1984 to 1992.
For Glasgow, Males.



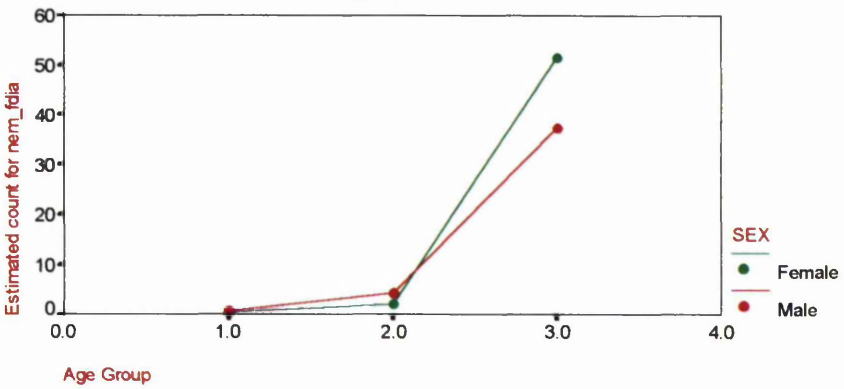
Plot 3-9-37 : Plot of estimated count for em_sdia (first ad. of type 4)
in different age groups over years 1984 to 1992.
For Motherwell, Males.



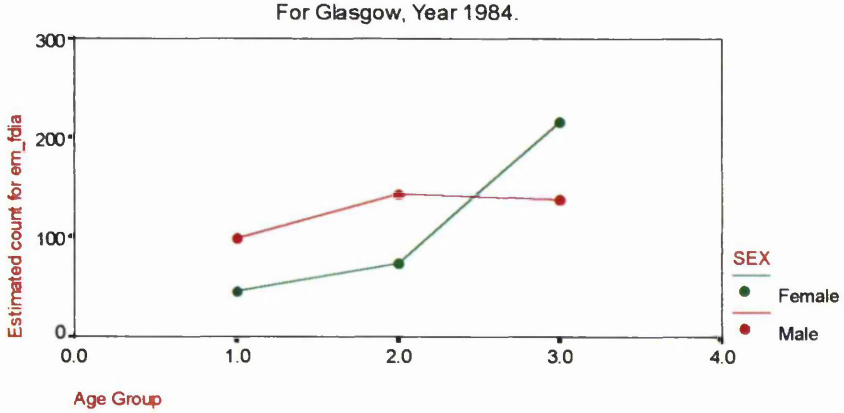
Plot 3-9-38 : Plot of estimated count for em_sdia (first ad. of type 4)
in different age groups over years 1984 to 1992.
For pooled cities (Dun. Kil. Pai.), Males.



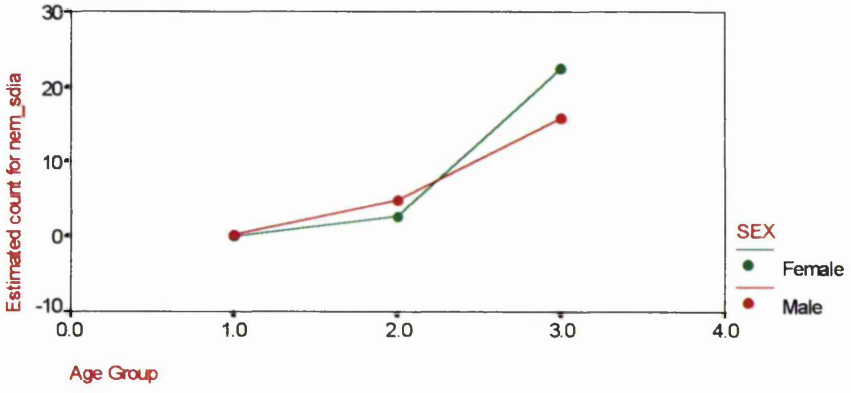
Plot 3-9-39 : Plot of estimated count for nem_fdia (first ad. of type 1)
in different sexes against age groups.
For Glasgow, Year 1984.



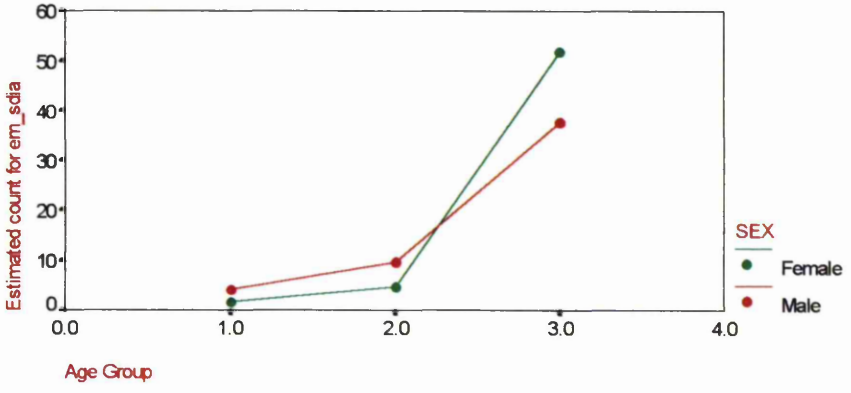
Plot 3-9-40 : Plot of estimated count for em_fdia (first ad. of type 2)
in different sexes against age groups.
For Glasgow, Year 1984.



Plot 3-9-41 : Plot of estimated count for nem_sdia (first ad. of type 3)
in different sexes against age groups.
For Glasgow, Year 1984.



Plot 3-9-42 : Plot of estimated count for em_sdia (first ad. of type 4)
in different sexes against age groups.
For Glasgow, Year 1984.



3-10 : Summary:

We summarise the present chapter, concerning first admissions, as follows.

In 3-3 we distinguished the four types : Non-emergency/emergency and first/second diagnosis.

In 3-4 we fitted a loglinear model to the counts of the main type (emergency first diagnosis) in a fourway contingency table with 1008 cells. It seemed advisable to drop one city, and permissible to pool three others. All adult first admissions were also pooled, regardless of precise age or marital status. We noted however (plot 3-4-5) the much steeper increase over the years, in Aberdeen, in first admissions of single, compared to married, patients aged 15-40 years.

Finally all child patients (3-14 years) were pooled, leading to a grouped contingency table with 270 cells.

In 3-5 to 3-8 the four types of first admission were considered in turn. The main effects and the same 2-factor interactions as in 3-4 were fitted to the grouped contingency table. Validation was on the whole successful.

In 3-9 conclusions suggested by the models for counts of the four types of first admission were presented. Plots of estimated expectations of counts were shown illustrating:

a) different age patterns in cities (for all years and both sexes).

b)different trends in cities and age groups (for both sexes).

c) the different sex ratios for adults and children/babies (in all cities and years).

Chapter 4

Analysis of Later Asthma Admissions of Asthmatic Patients in a 3 Year Horizon After First Admission

In this chapter we model the later asthma admissions of asthmatic patients in a 3 year horizon after first asthma admissions. At first we investigate on which factor(s) the number of later admissions depends. These are the factors which have been measured or recorded at the time of first asthma admission. We will carry out these investigations by fitting some normal linear models to the mean of the number of later asthma admissions. We will also try to identify some important aspects of probability distribution function of later asthma admissions. By identifying important aspects of probability distribution function of later asthma admissions, we mean identifying, for example say, the probability of not returning to hospital (to any hospital in Scotland) or having more than two or more than three later asthma admissions after first admissions. The Logistic models will be used for this recent purpose.

As was said, in this chapter we intend to use two types of statistical model, normal linear models and logistic models. A brief but useful

introduction to these two types of model will be presented in two separate sections to remind the reader what these models are.

Just before going through next section, we remind the reader that the reasons for choosing a 3 year horizon for studying the later asthma admissions are discussed in section 2-7.

We also claimed (section 2-4) there is a significant seasonal effect on both first and later admissions which means the intensity of asthma admissions in some months of a year is more or less than the other months. Note that since we follow up each asthmatic patient for a full 3 years after first admission, there is no need to include the factor season in the model. The reason is that all patients have been influenced equally by this factor. Note also that since we are interested to follow up all patients for 3 years, we restricted the date of first admission up to end of year 1989 i.e. in all analyses of later admissions, which are due to 3 years horizon after first admission, we have considered only those patients (or later admissions of those patients) whose date of first admission occurred between first of January 1984 and end of December 1989 (only 6 cohorts 1984 to 1989).

4-1 : An Introduction to Normal Linear Models:

We shall consider various models for the dependence of a patient's number X_{ijklr} of later admissions (in a 3 years horizon) on four factors indexed i, j, k, l, where r indicates the individual patient:

$$E(X_{ijklr}) = \theta_{ijkl}$$

$$Var(X_{ijklr}) = \sigma^2_{ijkl}$$

In 4-3 we fit various factorial expressions to θ_{ijkll}, using the summary statistics

$$\overline{X}_{ijkl}$$

and

$$\hat{\sigma}^2_{ijkl} = (n_{ijkl} - 1)^{-1} \sum_{r=1}^{n_{ijkl}} (X_{ijklr} - \overline{X}_{ijkl})^2$$

Since $Var(\overline{X}_{ijkl}) = \sigma^2_{ijkl} / n_{ijkl}$, we require weighted ANOVAs of the X_{ijkl}, with weights:

$$n_{ijkl} / \sigma^2_{ijkl} .$$

For a cell to contribute to the analysis we should have

$$n_{ijkl} \geq 2.$$

If σ^2_{ijkl} were all known the statistical analysis, assuming Normality of the Means X_{ijkl} , would resemble ordinary unweighted ANOVA, with exact F tests to remove from the model (or to add to it) a set of factorial terms.

Since σ^2_{ijkl} are all estimated, some with very small degrees of freedom $(n_{ijkl} - 1)$, the F tests presented are approximate.

As mentioned in 3-2, we use the standardised residuals to investigate the goodness fit of all models. Since we weight the means as well as assuming that they are Normally distributed, the definition of standardised Pearson is slightly different from 3-2.

4-2 : An Introduction to Logistic Models (Regression) :

The number of successful events in n ($n \geq 1$) repetition of a trial is often regarded as a Binomial random variable. Hence;

$$Y_i \sim B(n_i , \theta_i)$$

where θ_i is the probability of occurrence of a defined event (such as "Not returning to hospital" or " having more than two later admissions" and so on) in a single trial (i.e. for a single patient). The subscript i is referred to a group of individuals in i-th combination of some factors. It is assumed that the individuals in a particular combination of factors, have common probability of having success.

A logistic model assumes a simple factorial form for the logit of θ which is defined as;

$$\varphi_i = \text{Logit}\ (\theta_i) = \text{Log}\ [\theta_i / 1-\theta_i].$$

Then,

$$\theta_i = \exp(\varphi_i)/[1+\exp(\varphi_i)]$$

In an additive model of this kind, the interest tends to focus on main effects of factors which are included in the model.

In the GLIM statistical package, used here, the term "scaled deviance" stands for the likelihood ratio statistic $2\log\lambda$ for testing a model within the saturated model. The null distribution of $2\log\lambda$ is approximately χ^2.

The Pearson residual, which we use to investigate the goodness fit of the logistic models as well, is defined as,

$$r^{p}_{i} = (y_i - \hat{y}_i)/\sqrt{[\hat{\theta}_i(1-\hat{\theta}_i)n_i)]}.$$

while the standardised Pearson residuals are defined as:

$$r^{ps}_{i} = r^{p}_{i} /\sqrt{(1-h_i)}$$

4-3 : Modelling the Mean of Number of Later Asthma Admissions in a 3 Year Horizon After First Admission, Using A Normal Linear Model (Weighted Regression) :

In this section we intend to model the asthmatic patients' mean of number of later admissions in a 3 year horizon after first asthma admission. The final aim of this section is to investigate on which factor(s) the mean of later asthma admissions of each asthmatic patients depends. To carry out this idea, the mean of number of later asthma admissions in a 3 year horizon after first admission, in each combination of 4 factors age group, sex, year of first asthma admission and city, was calculated. We remind the reader that, considering the levels of the mentioned four factors, there are $3\times2\times6\times5=180$ of such means, one for each combination of levels of the 4 factors. Note that for some type of first admission, there are not any first admissions in some particular combination of levels of 4 factors i.e. some cells (some of 180 cells) for some type of first admission, contain no patients. Hence in this case the corresponding cell has no mean of later admissions. It implies that for some type of first admission we will have less than 180 means of later admissions. The mentioned mean, in each cell, was calculated by dividing the total number of later asthma admissions (in a particular cell) by total number of patients in that particular cell.

We decided to fit ordinary linear normal model (Regression model with factors as explanatory variables) to means of later asthma admissions in different cells. Note it is the most usual consideration to assume the mean of later admissions is normally distributed. There is no reason to believe this assumption is incorrect. Note some of these means which are due to large number of patients should be taken more seriously than the others which do not. It implies we should consider a weighted normal linear model (weighted regression model) to be able to weight different means differently. The weighted regression model was introduced in section 4-1. Here, the weight, which is going to be considered for each mean, is the inverse of variance of the number of later asthma admissions in a particular cell i.e. weight = n/var(x) where x is the number of a patient's later admissions and n is the total number of patients in the cell. Once again, it is quite a usual weight which could be considered for any weighted regression model.

In using the GLIM package to fit a weighted regression model to data, one important point as was mentioned in section 4-1, should not be forgotten. The point is that the deviance which is introduced by GLIM is actually the residual sum of squares of the fitted model. We mentioned in section 4-1 that to carry out a test to investigate whether the factor, which is entered recently in the model, is significantly related to response variable or not, we should calculate the value of F statistic. We mentioned also that no precise test is possible.

4-3-1 : Modelling the Mean of Number of Later Asthma Admissions in a 3 Year Horizon After First Admission, for first admissions of type 1 :

In this section we use a weighted regression model to investigate on which factor(s) the mean of number of later asthma admissions (in 3 a year horizon after first admission) depends. Here we carry out the analysis only for those patients whose first asthma admissions are type 1. Recall that first admission of type 1 is due to those patients whose first reason of hospitalisation are asthma and have been admitted to hospital as non emergency cases.

Table 4-3-1-1 shows the weighted regression model which is fitted to mean of later asthma admissions of above mentioned patients. The table indicates that, for patients with first admissions of type 1, none of 4 factors age group, sex, year of first admission and city are related to mean of later admissions in 3 years horizon after first admissions i.e. these factors has no effect on the occurrence of later admissions of these patients. Since the model of table 4-3-1-1 includes only the constant term, no plot was prepared to investigate the goodness of fit of the model. Note that only 72 cells were used in model 4-3-1 (instead of 180 cells). it is because not only some cells are empty (i.e. include no patient) but some the variance can not be calculated for those cells which include only one patient. We encounter this in later sections as well.

Table 4-3-1-1 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For the asthmatic patients whose first asthma admissions are type 1.

Final model includes only constant term.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Age				0.46	(2,69)	P=.6332, , N.S.
Sex				0.1918	(1,70)	P=.6628, N.S.
Year				0.581	(5,66)	P=.7144, N.S.
City				2.311	(4,67)	P=.0667, N.S.
Age.Sex+ Age+Sex				0.782	(5,66)	P=.5663, N.S.
Age.Year+ Age+Year				0.636	(16,55)	P=.8404, N.S.
Age.City+ Age+City				1.64	(12,59)	P=.1051, N.S.
Sex.Year+ Sex+Year				2.246	(11,60)	P=.0531, N.S.
Sex.City+ Sex+City				2.149	(9,62)	P=.0682, N.S.
Year.City+ Year+City				1.64	(27,44)	P=.0708, N.S.

deviance = 67.571 residual df = 71 from 72 observation.

	estimate	s.e.	parameter
1	0.3596	0.025481192	1(constant)

scale parameter 0.9517

4-3-2 : Modelling the Mean of Number of Later Asthma Admissions in a 3 Year Horizon After First Admission, for first admissions of type 2 :

Table 4-3-2-1 shows the weighted regression model which is fitted to mean of later asthma admissions of the patients whose first asthma admissions are type 2. These are later asthma admissions in a 3 year horizon after first asthma admissions. The table indicates that, for patients whose first admissions are type 2, two factors age group (at time of first asthma admission) and sex of patients and also the interaction between these two factors are strongly related to mean of number of later asthma admissions in a 3 year horizon after first admission. The table shows that the factor "Year of first admission" and also its interaction with age group are also just significantly related to the mentioned mean.

Table 4-3-2-1 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For the asthmatic patients whose first asthma admissions are type 2.

Final model : $C+\alpha(Age)+\beta(Sex)+\gamma(Year)+\eta(Age.Sex)+\lambda(Age*Year)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Age.Sex	9.703	(2,160)	P=.0001, Sig.			
Age.Year	2.29	(10,158)	P=.0155, Sig.			
City				1.66	(4,154)	P=.1621, N.S.
Age.City+City				1.566	(12,146)	P=.1077, N.S.
Sex.Year				0.574	(5,153)	P=.7198, N.S.
Sex.City+City				1.322	(8,150)	P=.2367, N.S.
Year.City+City				1.45	(24,134)	P=.0961, N.S.

deviance = 218.87 residual df = 158 from 179 observations

	estimate	s.e.	parameter
1	0.9434	0.06134	1
2	-0.6634	0.09462	FAGE_GRP(2)
3	-0.5059	0.07804	FAGE_GRP(3)
4	0.1040	0.05357	SEX(2)
5	-0.06613	0.08578	F_YEAR(2)
6	-0.06251	0.08494	F_YEAR(3)
7	0.06575	0.08891	F_YEAR(4)
8	-0.07433	0.08102	F_YEAR(5)
9	-0.04688	0.08403	F_YEAR(6)
10	0.2053	0.06850	FAGE_GRP(2).SEX(2)
11	-0.04654	0.06364	FAGE_GRP(3).SEX(2)
12	0.01587	0.1208	FAGE_GRP(2).F_YEAR(2)
13	-0.02564	0.1231	FAGE_GRP(2).F_YEAR(3)
14	-0.3007	0.1161	FAGE_GRP(2).F_YEAR(4)
15	-0.0008024	0.1192	FAGE_GRP(2).F_YEAR(5)
16	-0.06248	0.1166	FAGE_GRP(2).F_YEAR(6)
17	0.07131	0.1039	FAGE_GRP(3).F_YEAR(2)
18	0.07379	0.1068	FAGE_GRP(3).F_YEAR(3)
19	-0.04691	0.1080	FAGE_GRP(3).F_YEAR(4)
20	0.008852	0.09929	FAGE_GRP(3).F_YEAR(5)
21	-0.01323	0.1000	FAGE_GRP(3).F_YEAR(6)

scale parameter 1.385

Table 4-3-2-1 (recently mentioned table) indicates that children and adults are less likely to return to hospital (smaller mean of later asthma admissions) than babies. A comparison between children and adults (using estimated coefficients in the model) shows that children are much less likely to return to hospital than adults. It implies that babies and children have, respectively, the greatest and the smallest risk of returning to hospital.

The fitted model shows female has greater mean of later admissions than males i.e. in a 3 year horizon after first asthma admission, females return, in average, to hospitals more frequently than males. Thus female first admissions appear (on average) more seriously ill than male first admissions. Recall that (section 2-8.) we discovered previously that males' first admissions are more frequent than females' first admissions. Possibly family or GPs attitudes are such that male and female cases of equal seriousness are not treated equally,

when candidates for first admission. Boys may complain more and/or parents may take more notice.

Note that the factor 'City' is not included in the model. It implies that the suggestion in section 2-8 that patients corresponding to two cities Edinburgh and Motherwell have more later admissions than expected (compared with other cities) is not supported by further analyses.

Table 4-3-2-1 indicates that even though the means of later asthma admissions for patients correspond to different cohorts of first admissions (i.e. different year of first asthma admissions) are not significantly different, the interaction between this factor and "age group" is significantly related to mean of number of later admissions. This interaction implies that the effect of cohort of first asthma admission (i.e. "year of first admission") on mean of later admission is different for babies, children and adults. Since only one of the coefficients due to the mentioned interaction is significant, it is difficult to make any comment or to interpret the interaction between these two factors. The mentioned significant interaction term is due to "children" and "cohort 1987". We investigated whether the significant interaction, which we got between children age group and "cohort of first admission 1987", is due to some outliers in the data or not. We could not find any outlier in the data due to this age group or year 1987. As we will discuss in next paragraphs, the model is not well fitted. Note it could lead us to have some strange results. However if the model is valid, then it means that those children whose first asthma admissions have occurred in year 1987 have a different expectation of later admissions.

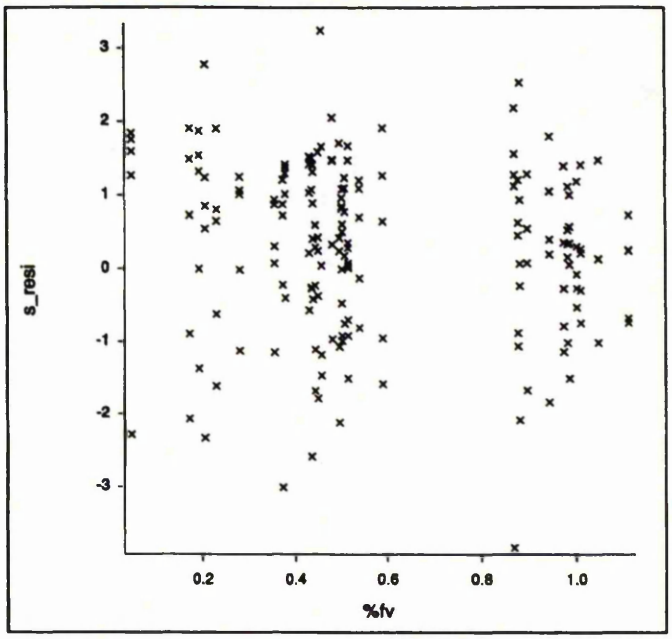
Table 4-3-2-1 suggests the factor "city" has no effect on mean of later asthma admissions. It indicates that patients whose city of first hospitalisation is different have actually similar mean of later asthma admissions.

Plot 4-3-2-1 shows the scatter plot of standardised Pearson residuals of the model of table 4-3-2-1 against the fitted values. The plot indicates some clear pattern for variance of standardised residuals. There is a tendency for large means to have smaller variance. Note it implies the model of table 4-3-2-1 is not well fitted to the means of later asthma admissions. The plot 4-3-2-2, which shows the scatter plot of fitted values against the actual values for the mentioned model, indicates again that the model of table 4-3-2-1 is not well fitted to the data.

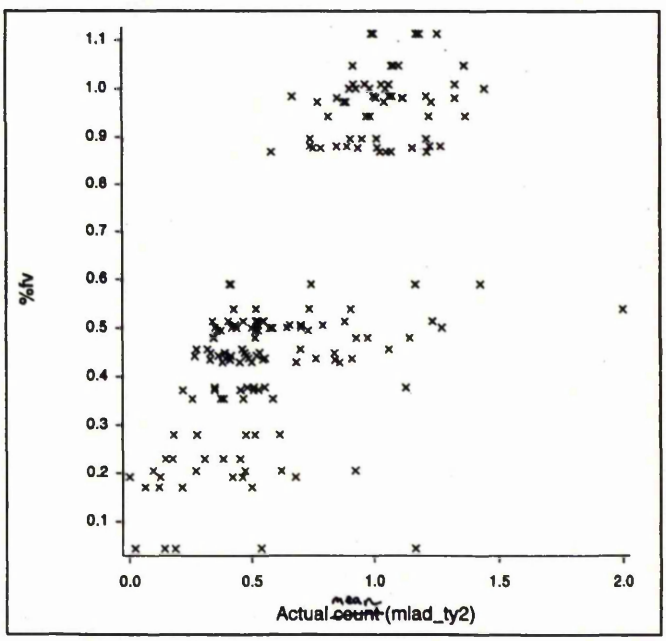
Plots 4-3-2-1 and 4-3-2-2 both show a more serious problem with the fitted model than not being good for prediction or not having constant variances for residuals. The problem is the separation which exists in response variable for the patients. Both plots suggest that there are two groups of responses and these two groups of responses are completely separated. The separation between the responses indicates we have fitted a common model to two different response variables. After some investigation we found out that one group of these responses belong to babies and the another one belong to children and adults. It implies we should fit separate model to means of later asthma admissions due to babies and due to children and adults (together). It may help us to achieve a better fit for the model as well as we may get some different results from that we got from model of table 4-3-2-1.

Table 4-3-2-2 shows the weighted regression model which is fitted to mean of later asthma admissions of the patients in babies age group. The model shows that the mean of later asthma admissions of babies is not related to any of 3 factors "sex", "year of first admissions" or "city". It implies that males' or females' babies from different cities and with different years of first admission (from 1984 to 1989) have similar mean of later asthma admissions. Since the

Plot 4-3-2-1 : Scatter plot of standardised Pearson residuals against fitted Values for model of table 4-3-2-1.



Plot 4-3-2-2 : Scatter plot of fitted Values against actual values for model of table 4-3-2-1.



constant term is the only term which is included in model 4-3-2-2, therefore no plots was prepared to investigate the goodness of fit of The model.

Table 4-3-2-2 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For babies, first asthma admissions type 2.
Final model includes only constant term.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Sex				3.98	(1,58)	P=.0507, N.S.
Year				0.885	(5,53)	P=.4977, N.S.
City				2.073	(4,54)	P=.0971, N.S.

deviance = 71.706 residual df = 59 from 60 observations.

	estimate	s.e.	parameter
1	0.9406	0.02301	1

scale parameter 1.215

Table 4-3-2-3 shows the weighted regression model which is fitted to mean of later asthma admissions due to both children (3-14 years old) and adults (more than 14 years old) patients. Note we have ignored the babies patients. The table indicates that factors "age group" (children and adults), "sex", the interaction between "age group" and "sex", and both "year of first admission" and the interaction between the "year of first admission" and "age group" are significantly related to the mean of later asthma admissions of these patients. The factor "age group" has a very strong effect on mean of later admissions and adults return to hospital more frequently than children. Note this result is similar to the result which we had got from the model of table 4-3-2-1. The table suggests females (either children or adults) are more likely than males to return to hospital after first asthma admission. Once again, this result is also similar to the one which we got from the model of table 4-3-2-1. Table 4-3-2-3 indicates the mean of later asthma admissions of those patients whose

first admissions have occurred in year 1987 (cohort 1987), is significantly smaller than other patients. This table suggests also that the effect of year 1987 on the mean of later admissions is different for children and adults (note interaction term in the model). It indicates that those adults whose year of first asthma admissions were at year 1987, are more likely to return to hospitals than those children whose first admissions have occurred in year 1987. Once again, we tried to find some explanation for having different means of later asthma admissions for the patients who were admitted as the first time in year 1987, but unfortunately we could not. We also tried to find out whether this result is due to some outliers or not. As long as we tried we could not find any outlier.

Table 4-3-2-3 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For children and adults asthmatic patients whose first asthma admissions are type 2.

Final model : $C+\alpha(Age)+\beta(Sex)+\gamma(Year)+\eta(Age.Sex)+\lambda(Age.Year)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Age.Sex	16.569	(1,106)	P=.0001, Sig.			
Age.Year	2.58	(5,105)	P=.0304, Sig.			
City				1.55	(4,101)	P=.1935, N.S.
Age.City+City				1.409	(8,97)	P=.2024, N.S.
Sex.City+City				1.035	(8,97)	P=.4154, N.S.
Sex.Year				0.733	(5,100)	P=.6004, N.S.
City.Year+City				1.28	(24,81)	P=.2053, N.S.

	estimate	s.e.	parameter
1	0.2708	0.08227	1
2	0.1442	0.08992	FAGEGRP2(2)
3	0.3056	0.04420	SEX2(2)
4	-0.07759	0.08852	F_YEAR2(2)
5	-0.1044	0.09463	F_YEAR2(3)
6	-0.2591	0.07950	F_YEAR2(4)
7	-0.09086	0.09249	F_YEAR2(5)
8	-0.1303	0.08473	F_YEAR2(6)
9	0.05230	0.04585	F_CITY2(2)
10	0.06655	0.04275	F_CITY2(3)
11	-0.03182	0.05149	F_CITY2(4)

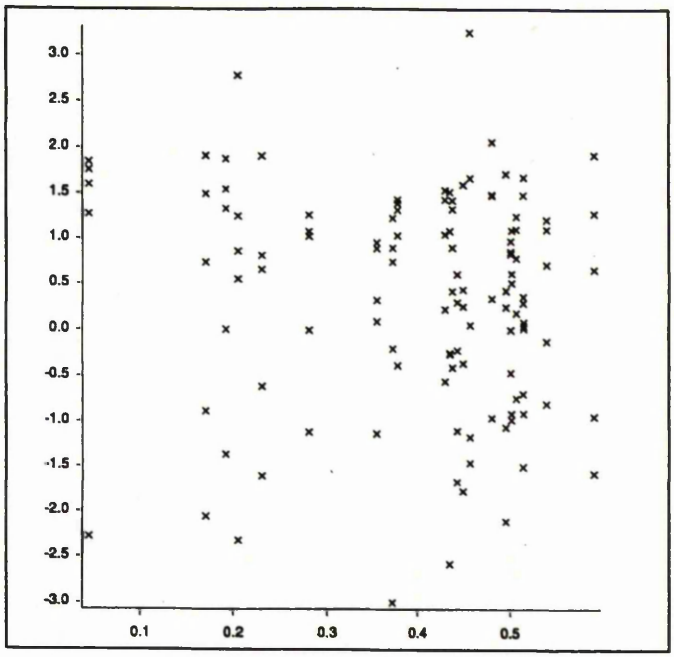
```
    12      0.03081      0.04270      F_CITY2(5)
    13      -0.2471      0.05662      FAGEGRP2(2).SEX2(2)
    14      0.07616       0.1072      FAGEGRP2(2).F_YEAR2(2)
    15       0.1027       0.1162      FAGEGRP2(2).F_YEAR2(3)
    16       0.2719       0.1011      FAGEGRP2(2).F_YEAR2(4)
    17      0.02076       0.1105      FAGEGRP2(2).F_YEAR2(5)
    18      0.05320       0.1015      FAGEGRP2(2).F_YEAR2(6)
scale parameter 1.473
```

Plots 4-3-2-3 and 4-3-2-4 are prepared to investigate the goodness of fit of the model of previous paragraph. Plot 4-3-2-3 shows the scatter plot of standardised Pearson residuals against the fitted values. It shows some small changes in variance of fitted values which is not really very serious. Plot 4-3-2-4 shows the scatter plot of fitted values against the actual values. This plot indicates the fitted model is not very well to be used for prediction. Considering a horizontal line, such as fitted=0.5, we see the skewness of the distribution of actual mean counts.

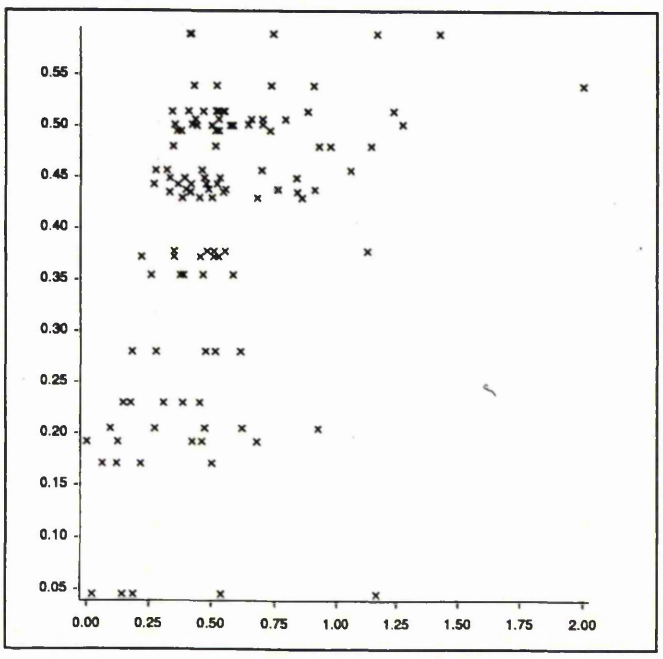
It was mentioned before that we got a strange result in table 4-3-2-3 which suggested those patients whose dates of first admission are in year 1987 (cohort 1987), were less likely than other patients to return to hospitals. We checked and compared the fitted values and actual values with each other and it was discovered that fitted values are much smaller than the actual values. To check the results of the model of table 4-3-2-3 once more, and also to discover whether the results are due to some extreme large means or not, it was decided to fit a weighted regression model to those means of later asthma admissions which are not extremely large. Note if we get same results as before, it will implies that the results of model of table 4-3-2-3 are consistent and therefore could be reliable.

Table 4-3-2-4 shows the weighted regression model which is fitted to those means of later asthma admissions which are less than 1.000. Note this model is fitted to only children and adults patients. The table suggest that same

Plot 4-3-2-3 : Scatter plot of standardised Pearson residuals against fitted Values for model of table 4-3-2-3.



Plot 4-3-2-4 : Scatter plot of fitted Values against actual values for model of table 4-3-2-3.



factors and interaction terms are entered in this model as in the model of table 4-3-2-3. The only difference is the interaction between two factors "age group" and "year of first admission" which is no longer significantly related to mean of later admissions. Plots 4-3-2-5 and 4-3-2-6 shows same pattern as plots 4-3-2-3 and 4-2-3-4.

Table 4-3-2-4 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For children and adults asthmatic patients whose first asthma admissions are type 2 and their mean is less than 1.

Final model : $C+\alpha(Age)+\beta(Sex)+\gamma(Year)+\eta(Age.Sex)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Year	3.19	(5,106)	P=.0101, Sig.			
Age.Sex	15.66	(1,102)	P=.0001, Sig.			
Age.Year				2.09	(5,96)	P=.0732, N.S.
City				1.58	(4,97)	P=.1857, N.S.
Age.City+City				1.882	(8,93)	P=.0720, N.S.
Sex.Year				1.48	(5,96)	P=.2035, N.S.
Sex.City+City				1.25	(8,93)	P=.2794, N.S.
Year.City+City				1.28	(24,77)	P=.2072, N.S.

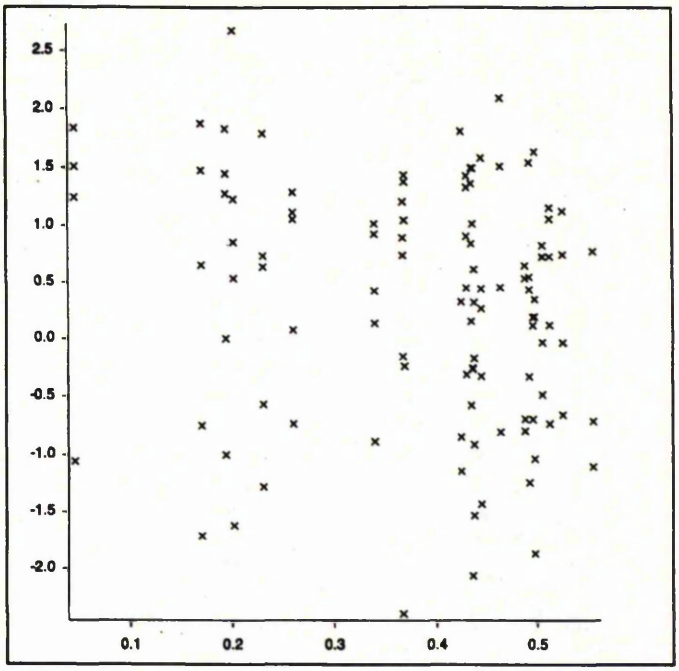
deviance = 143.43 residual df = 101 from 110 observations

	estimate	s.e.	parameter
1	0.2022	0.04269	1
2	0.2439	0.03352	FAGEGRP2(2)
3	0.3075	0.04294	SEX2(2)
4	0.005479	0.04847	F_YEAR2(2)
5	-0.007093	0.05251	F_YEAR2(3)
6	-0.1312	0.04457	F_YEAR2(4)
7	-0.05342	0.04856	F_YEAR2(5)
8	-0.05964	0.04530	F_YEAR2(6)
9	-0.2370	0.05538	FAGEGRP2(2).SEX2(2)

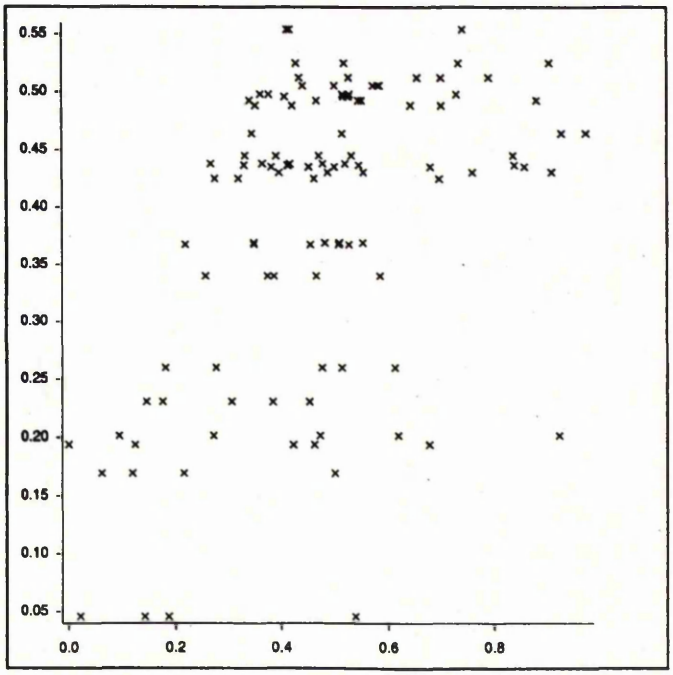
scale parameter 1.420

Table 4-3-2-5 shows the weighted regression model which is similar to model of table 4-3-2-4 but it is fitted to those means of later admissions which are less than 0.8. Once again, similar factors and interaction terms were

Plot 4-3-2-5 : Scatter plot of standardised Pearson residuals against fitted Values for model of table 4-3-2-4.



Plot 4-3-2-6 : Scatter plot of fitted Values against actual values for model of table 4-3-2-4.



significantly related to mean of number of admissions. Plots 4-3-2-7 and 4-3-2-8 are the plots which show how well the model of table 4-2-3-5 is fitted. Tables 4-3-2-4 and 4-3-2-5 together, suggest that the result of model of table 4-3-2-3 could be relatively reliable.

Table 4-3-2-5 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For children and adults asthmatic patients whose first asthma admissions are type 2 and their mean is less than 0.8.

Final model : $C+\alpha(Age)+\beta(Sex)+\gamma(Year)+\eta(Age.Sex)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Year	3.406	(5,97)	P=.0071, Sig.			
Age.Sex	14.188	(1,93)	P=.0003, Sig.			
Age.Year				2.042	(5,87)	P=.0806, N.S.
City				2.004	(4,88)	P=.1009, N.S.
Age.City+ City				2.01	(8,84)	P=.0549, N.S.
Sex.Year				1.492	(5,87)	P=.2007, N.S.
Sex.City+ City				1.693	(8,84)	P=.1120, N.S.
Year.City+ City				1.533	(24,68)	P=.0871, N.S.

deviance = 121.32 residual df = 92 from 101 observations

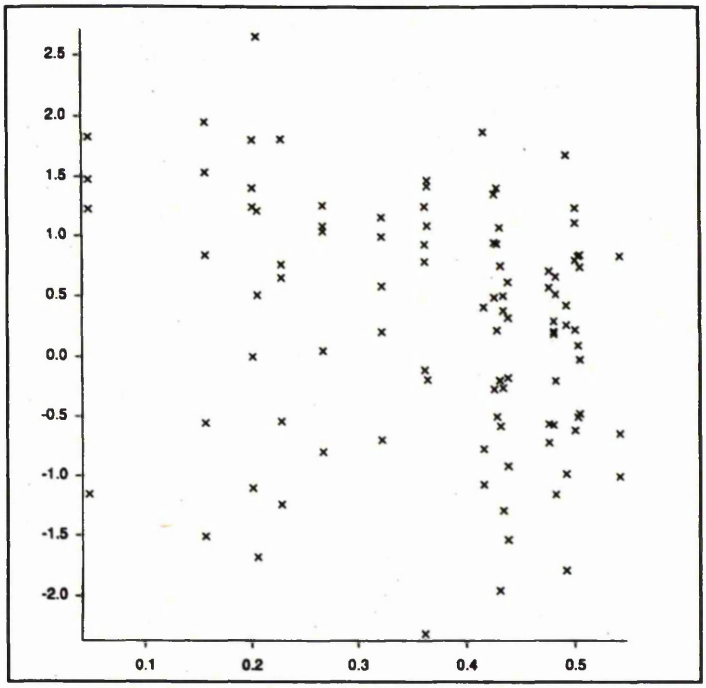
	estimate	s.e.	parameter
1	0.2046	0.04131	1
2	0.2389	0.03241	FAGEGRP2(2)
3	0.2890	0.04204	SEX2(2)
4	0.005216	0.04690	F_YEAR2(2)
5	-0.009717	0.05092	F_YEAR2(3)
6	-0.1331	0.04315	F_YEAR2(4)
7	-0.05447	0.04705	F_YEAR2(5)
8	-0.06713	0.04395	F_YEAR2(6)
9	-0.2198	0.05402	FAGEGRP2(2).SEX2(2)

scale parameter 1.319

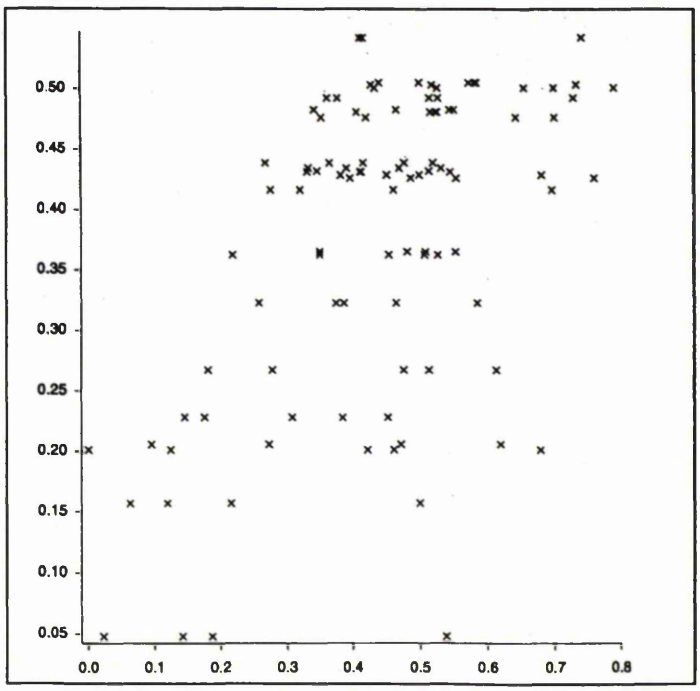
Finally, the fitted models (in this section) suggest the mean of later asthma admissions (in a 3 year horizon after first asthma admission) of those

patients whose first asthma admissions are type 2 (emergency admission and asthma as the first reason of hospitalisation) is related to factors "age group", "sex", the interaction between "age group" and "sex", and also to "year of first admission" (in particular year of first admission equal to 1987). Babies return to hospitals more frequently than children and adults, and adults return more than children i.e. children have a lower mean of later asthma admissions in compared to babies and adults. Among babies mean of later asthma admissions (in a 3 year horizon after first asthma admission) is not related to any other factor, and not even related to factor "sex". For two other age groups (children and adults), the mentioned mean, in addition to age group, is related to factors "sex", interaction between "age group" and "sex", and also to "year of first admission". Female children and adults return to hospital more often than males.

Plot 4-3-2-7 : Scatter plot of standardised Pearson residuals against fitted Values for model of table 4-3-2-5.



Plot 4-3-2-8 : Scatter plot of fitted Values against actual values for model of table 4-3-2-5.



4-3-3 : Modelling the Mean of Number of Later Asthma Admissions in a 3 Year Horizon After First Admission, for first admissions of type 3 :

We remind the reader that first admissions of type 3 are first asthma admission of those patients who were hospitalised as non emergency cases and asthma is their second reason of hospitalisation. In this section we intend to model their mean of later asthma admissions in a 3 year horizon after first asthma admission.

Table 4-3-3-1 shows the weighted regression model which is fitted to mean of later admissions of those patients whose first asthma admissions are type 3. The table shows that none of 4 factors "age group", "sex", "year of first admissions" or "city" is related to the mentioned mean. No plot was prepared to investigate the goodness of fit of the model 4-3-3-1.

Table 4-3-3-1 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 3.

Final model includes only constant term.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	**d.f.**	**Result**	**Test Statistic**	**d.f.**	**Results**
Age				2.24	(2,48)	P=.1175, N.S.
Sex				2.38	(1,49)	P=.1293, N.S.
Year				2.33	(5,45)	P=.0578, N.S.
City				0.652	(4,46)	P=.6284, N.S.
Age.Sex+ Age+Sex				1.128	(5,45)	P=.3594, N.S.
Age.Year+ Age+Year				2.092	(14,36)	P=.0575, N.S.
Age.City+ Age+City				1.16	(11,39)	P=.3451, N.S.
Sex.Year+ Sex+Year				2.74	(11,39)	P=.0600, N.S.
Sex.City+ Sex+City				0.881	(9,41)	P=.5498, N.S.
Year.City+ Year+City				1.138	(23,27)	P=.3706, N.S.

deviance of the model with constant term = 40.97 d.f. = 50.

	estimate	s.e.	parameter
1	0.1699	0.01976	1

scale parameter 0.8194

4-3-4 : Modelling the Mean of Number of Later Asthma Admissions in a 3 Year Horizon After First Admission, for first admissions of type 4 :

Table 4-3-4-1 shows the weighted regression model which is fitted to mean of number of later asthma admissions (in a 3 year horizon after first asthma admission) of those patients whose first asthma admissions are type 4. Recall that first admissions of type 4 are first admissions of those patients who were admitted as emergency cases and asthma has been their second reason of hospitalisation. The table indicates that the mean of later asthma admissions of these patients is significantly related to two factors
"age group" and "sex". The model suggests both children and adults are less likely than babies to return to hospitals. Comparing two age groups children and adults, shows that adults are less likely than children to return to hospitals. Note this recent result is different from that we got for first admission of type 2. Once again, the mean of later asthma admissions of females is greater than males' mean of later asthma admissions. Plots 4-3-4-1 and 4-3-4-2 are the plots which were prepared to investigate the goodness of fit of the model 4-3-4-1. The 2×3 combinations of the fitted factors Sex and Age are apparent. The plot of standardised residuals is satisfactory.

Table 4-3-4-1 : Weighted normal linear model for mean of later asthma admissions in a 3 years horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 4.

Final model : $C+\alpha(Age)+\beta(Sex)$.

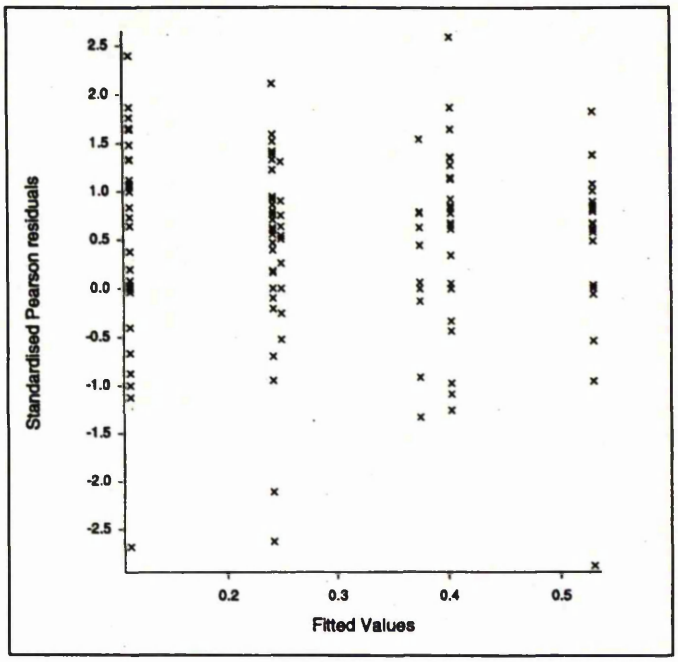
Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic	d.f.	Result	Test Statistic	d.f.	Results
Age	135.5	(2,121)	P<.0001, Sig.			
Sex	14.8	(1,120)	P=.0002, Sig.			
Year				0.93	(5,114)	P=.4644, N.S.
City				1.88	(4,115)	P=.1186, N.S.
Age.Sex				0.705	(2,117)	P=.4962, N.S.
Age.Year+Year				1.433	(15,104)	P=.1458, N.S.
Age.City+City				1.619	(12,107)	P=.0969, N.S.
Sex.Year+Year				1.208	(10,109)	P=.2939, N.S.
Sex.City+City				1.124	(8,111)	P=.3528, N.S.
Year.City+ Year+City				1.09	(29,90)	P=.3677, N.S.

deviance = 144.60 residual df = 119 from 123 observations

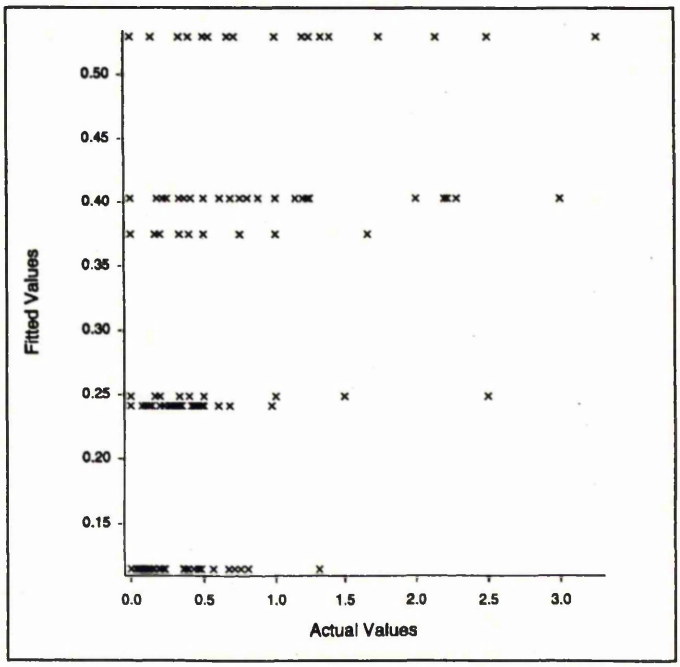
	estimate	s.e.	parameter
1	0.4030	0.05080	1
2	-0.1543	0.07873	FAGE_GRP(2)
3	-0.2878	0.05211	FAGE_GRP(3)
4	0.1261	0.03075	SEX(2)

scale parameter 1.215

Plot 4-3-4-1 : Scatter plot of standardised Pearson residuals against fitted Values for model of table 4-3-4-1.



Plot 4-3-4-2 : Scatter plot of fitted Values against actual values for model of table 4-3-4-1.



4-4 : Modelling Probability Distribution Function of Later Asthma Admissions at Some Particular Values (Using Logistic Models) :

In this section we intend to discover the relation between the probability distribution function of the number of later admissions of an asthmatic patient, and how it depends on the factors "age group at time of first asthma admission", "sex", "year of first admission" (i.e. cohort of first asthma admission) and "city of first asthma admission". Note all these factors identify the characteristics of the asthmatic patients at time of first asthma admission. Hence for fitting a logistic model we need to establish the values of the distribution function in which we intend to discover the relation between distribution function and the 4 mentioned factors. It means we should establish to which proportion of patients we intend to fit the model, the proportion of patients who never return to hospital (in a 3 year horizon after first asthma admission), or the proportion of patients who return to hospital more than 2 or 3 times. Note these values of later asthma admissions (0, 2 and 3) are 3 points of the probability distribution function of later asthma admissions. These mentioned proportions are, respectively, P(No. of later asthma admissions = 0), P(No. of later asthma admissions >2) and P(No. of later asthma admissions > 3).

As before, it was decided to fit separate logistic regression models to the mentioned proportions according to patients' type of first asthma admission. We

remind the reader that we established 4 types of first asthma admission due to 4 possible combinations of levels of two factors "Admission Type" and "Diagnosis Type". Note that in this case we are going to fit 3 logistic models (due to 3 points of probability function) to each of 4 groups of patients whose type of first asthma admission is different. Note that the number of later admissions is defined to include admissions of all types.

We remind the reader that as was explained in section 4-3, there are 180 different combinations of levels of 4 factors "age group", "sex", "year of first admission" and "city" but some of these cells (combinations), for some particular types of first admission, contain no first asthma admissions (i.e. no patient). It implies that when we are fitting different logistic models to different types of first asthma admission, we could expect to have different number of cells. As we will see in later sections, there are 140, 180, 150 and 172 non empty cells (i.e. containing at least one asthmatic patient) for first asthma admissions of, respectively , type 1, type 2, type 3 and type 4.

4-4-1 : Modelling Probability Distribution Function of Later Asthma Admissions of Patients Whose First Asthma Admission is Type 1 :

First of all we remind the reader that first asthma admissions of type 1 are those of first asthma admissions (or those of asthmatic patients) whose type of first asthma admission is non emergency and have been hospitalised with asthma diagnosis as the first reason of hospitalisation.

Table 4-4-1-1 shows the logistic model which is fitted to probability of "Not Returning to Hospital" in a 3 year horizon after first asthma admission of type 1. The model includes only the factor "sex" i.e. for those asthmatic patients whose type of first asthma admissions is type 1, the sex of patients is the only factor which affects significantly on the number of later asthma admissions. Note the coefficient of "sex" in the model is negative. It implies the probability of not returning in a 3 year horizon after first asthma admission, for first asthma admissions of type 1, depends only on sex of patients and females are less likely "not to return" to hospital than males i.e. They are more likely than males to return to hospital. It may indicate asthma attack is more serious for females (after the patient gets the asthma decease) than for males. We remind the reader we showed before that males are more likely than females to have a first asthma admission (chapter 3). Note this recent result implies that if a female has a first admission (type 1) then she is more likely than a male with a first admission (type 1) to return to hospital. So she is, on average, a more serious case than the males' first admission. This in turn suggests that a male is more likely to be offered a first admission than an equally serious female case.

This bias may operate within families. Table 4-4-1-1 indicates that other factors are not significantly related to probability of "Not Returning to Hospital" (for the asthmatic patients with this type of first asthma admissions).

Table 4-4-1-1 : Logistic model for probability of "Not Returning to Hospital" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 1.

Final model : C+β(Sex).

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Sex	5.54	1	P=.0186, Sig.			
Age				2.499	2	P=.2866, N.S.
Year				1.623	5	P=.8985, N.S.
City				2.707	4	P=.6080, N.S.
Age.Sex+Age				5.017	4	P=.2856, N.S.
Age.Year+ Age+Year				10.32	17	P=.8897, N.S.
Age.City+ Age+City				11.79	14	P=.6232, N.S.
Sex.Year+Year				6.99	10	P=.7264, N.S.
Sex.City+City				6.323	8	P=.6111, N.S.
Year.City+ Year+City				29.54	29	P=.4372, N.S.

```
scaled deviance =  159.13 residual df =  138
            estimate       s.e.      parameter
     1       1.187       0.1115      1
     2      -0.3471      0.1484      SEX(2)
scale parameter 1.000
```

Plots 4-4-1-1 to 4-4-1-3 are the plots that are prepared to investigate the goodness of fit of the model of table 4-4-1-1. Plot 4-4-1-1 (at end of the present section) shows the histogram of standardised Pearson residuals. Even though the histogram indicates skewness from the Normal distribution we note that the mean and standard deviation of the standardised Pearson residuals are very close, respectively, to 0 and 1. Plot 4-4-1-2 shows the plot of standardised

Pearson residuals against fitted values. The plot indicates some larger variance for those residuals which are due to small counts. Note that the Large Sample Theory (according to which the normal theory of residuals is applied to logistic models) might break down for small counts. For counts more than approximately 8 or 10, it seems the residuals' variance is roughly constant. However, the residuals' variance is larger for small counts, implies that the model is not well fitted. Plot 4-4-1-3 shows the plot of estimated number of patients (fitted values) who did not return to hospital against the actual values. As the plot indicates, the model is fairly well fitted for predictions.

Plot 4-4-1-1 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-1-1.

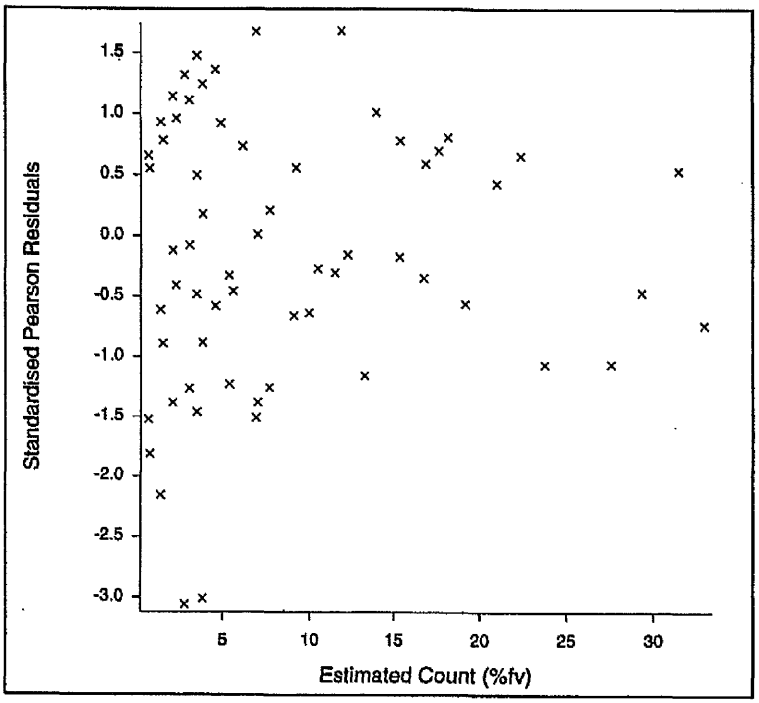
```
[-3.500,-3.000)  2 S
[-3.000,-2.500)  0
[-2.500,-2.000)  3 SS
[-2.000,-1.500)  8 SSSS
[-1.500,-1.000) 10 SSSSS
[-1.000,-0.500) 17 SSSSSSSSS
[-0.500, 0.000) 23 SSSSSSSSSSSS
[ 0.000, 0.500)  6 SSS
[ 0.500, 1.000) 57 SSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 1.000, 1.500) 12 SSSSSS
[ 1.500, 2.000]  2 S

Mean = 0.0323     S.D. = 0.9767
```

Table 4-4-1-2 shows the number of asthmatic patients (with first admission of type 1) with 0, 1, 2, 3 and more than 3 later asthma admissions in different sexes. Note that sex was the only factor which was significantly

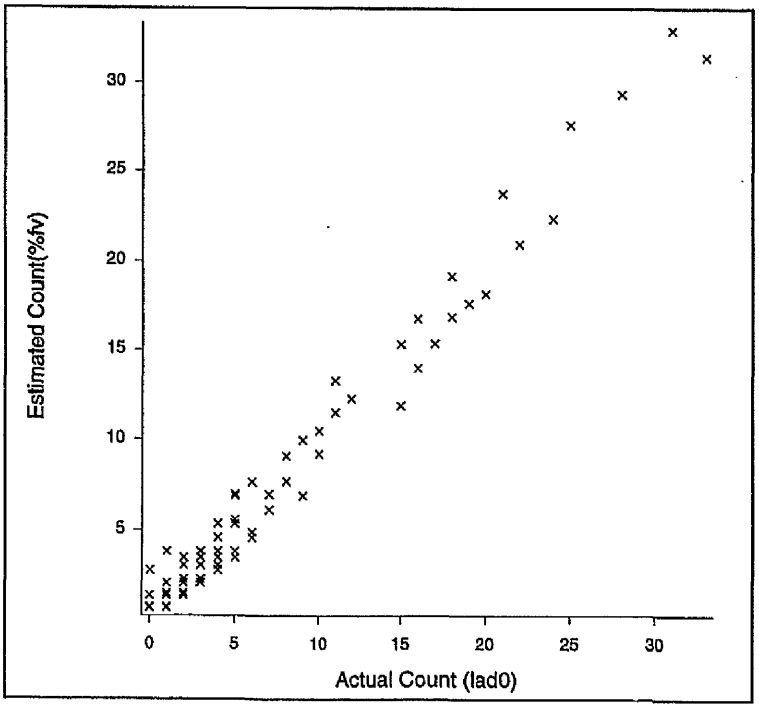
Table 4-4-1-2: Numbers of patients with different number of later admissions in different sexes.

	Numbers of later admissions					
	0	**1**	**2**	**3**	**More than 3**	**Total**
Male	344	70	19	5	11	449
Female	345	76	39	15	19	494
Total	689	146	58	20	30	943

Plot 4-4-1-2 : Scatter plot of standardised Pearson residuals against the fitted values for model of table 4-4-1-1.



Plot 4-4-1-3 : Scatter plot of fitted values against actual values for model of table 4-4-1-1.



related to probability of "returning to hospital".

Table 4-4-1-3 shows the logistic model which is fitted to probability of "having more than two later asthma admissions". This logistic model is for the patients whose first asthma admission have been distinguished as first asthma admission of type 1. This table indicates the probability of "Having more than two later asthma admissions" depends on none of four mentioned factors except "sex" and the interaction between "sex" and "year". The factor "year" of

Table 4-4-1-3 : Logistic model for probability of "Having More Than Two Later Asthma Admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 1.

Final model : $C+\beta(Sex)+\gamma(Year)+\eta(Sex.Year)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Sex.Year	12.58	5	P=.0276, Sig			
Age				4.037	2	P=.1329, N.S.
City				2.365	4	P=.6690, N.S.
Age.Sex+ Age				5.51	4	P=.2389, N.S.
Age.Year+ Age				16.74	12	P=.1596, N.S.
Age.City+ Age+City				15.78	14	P=.3270, N.S.
Sex.City+ City				3.69	8	P=.8840, N.S.
Year.City+ City				31.9	24	P=.1295, N.S.

```
scaled deviance = 83.36 residual df = 128
          estimate       s.e.      parameter
     1      -3.188     0.5102      1
     2       1.043     0.6015      SEX(2)
     3      -1.254      1.127      F_YEAR(2)
     4      0.2870     0.6865      F_YEAR(3)
     5      0.3167     0.7826      F_YEAR(4)
     6     0.03142     0.8841      F_YEAR(5)
```

7	-0.9059	1.129	F_YEAR(6)
8	0.9719	1.246	SEX(2).F_YEAR(2)
9	-2.560	1.256	SEX(2).F_YEAR(3)
10	-1.989	1.107	SEX(2).F_YEAR(4)
11	-0.7624	1.071	SEX(2).F_YEAR(5)
12	1.384	1.223	SEX(2).F_YEAR(6)

first asthma admission was not itself significantly related to the mentioned probability but since its interaction with "sex" was significant, it was included in the model.

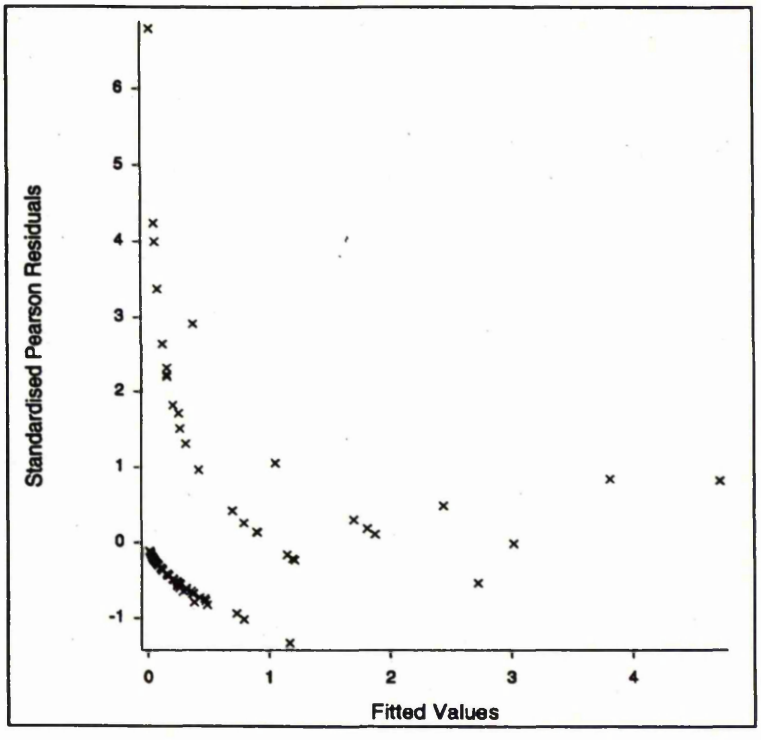
Plots 4-4-1-4 to 4-4-1-6 are prepared to investigate how well the model of table 4-4-1-3 fits. There is an outlier in the histogram of standardised Pearson residuals (plot 4-4-1-4) belonging to a cell which includes only one single patient who had more than three later admissions.

Plot 4-4-1-4 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-2-3.

```
[-1.600,-0.800)    4 S
[-0.800, 0.000) 110 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.800)    8 SSS
[ 0.800, 1.600)    6 SS
[ 1.600, 2.400)    6 SS
[ 2.400, 3.200)    2 S
[ 3.200, 4.000)    2 S
[ 4.000, 4.800)    1
[ 4.800, 5.600)    0
[ 5.600, 6.400)    0
[ 6.400, 7.200]    1
```

Table 4-4-1-4 shows the number of asthmatic patients (with first admission of type 1) with 0, 1, 2, 3 and more than 3 later asthma admissions in different sexes and cohorts of first admission. Recall that two factors sex and year were significantly related to probability of "having more than 2 later admissions".

Plot 4-4-1-5 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-1-3.



Plot 4-4-1-6 : Scatter plot of fitted values against actual values for model of table 4-4-1-3.

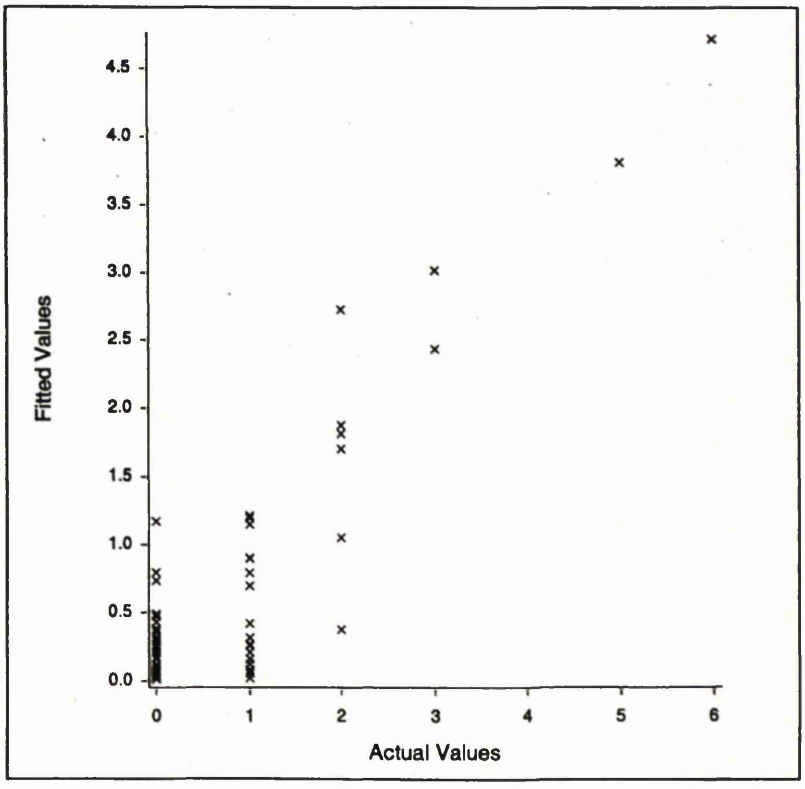


Table 4-4-1-4: Numbers of patients (of first admission of type 1) with different number of later admissions in different sexes and cohorts of first admission.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	77	18	2	2	2	101
	Female	76	14	4	2	9	105
	Total	153	32	6	4	11	206
1985	**Male**	68	12	5	1	0	86
	Female	51	8	9	4	2	74
	Total	119	20	14	5	2	160
1986	**Male**	73	13	5	0	5	96
	Female	61	14	8	0	1	84
	Total	134	27	13	0	6	180
1987	**Male**	40	11	2	2	1	56
	Female	70	13	8	1	1	93
	Total	110	24	10	3	2	149
1988	**Male**	38	6	3	0	2	49
	Female	48	19	4	3	1	75
	Total	86	25	7	3	3	124
1989	**Male**	48	10	2	0	1	61
	Female	39	8	6	5	5	63
	Total	87	18	8	5	6	124

Table 4-4-1-5 shows the logistic model which is fitted to probability of having more than three later asthma admissions for those patients whose first asthma admissions were type 1. Table shows that the probability of having more than three later admissions, for this group of patients, depends on factors sex, year of first admission and the interaction between them. Note that the model includes same factors as 4-4-1-1 and the factor Sex is included in all 3 logistic models of this section.

Since same factors and interaction terms are included in model 4-4-1-5 as in model 4-4-1-3 therefore we refer reader to table 4-4-1-4 to see the descriptive data of later admissions in different combinations of included factors.

Table 4-4-1-5 : Logistic model for probability of "Having More Than Three Later Asthma Admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 1.

Final model : $C+\beta(Sex)+\gamma(Year)+\eta(Sex.Year)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Sex.Year	12.54	5	P=.0281, Sig			
Age				0.507	2	P=.7761, N.S.
City				1.215	4	P=.8756, N.S.
Age.Sex+Age				1.67	4	P=.7962, N.S.
Age.Year+Age				9.489	12	P=.6607, N.S.
Age.City+ Age+City				11.18	14	P=.6718, N.S.
Sex.City+City				2.03	8	P=.9801, N.S.
Year.City+City				23.06	24	P=.5163, N.S.

scaled deviance = 60.176 residual df = 128

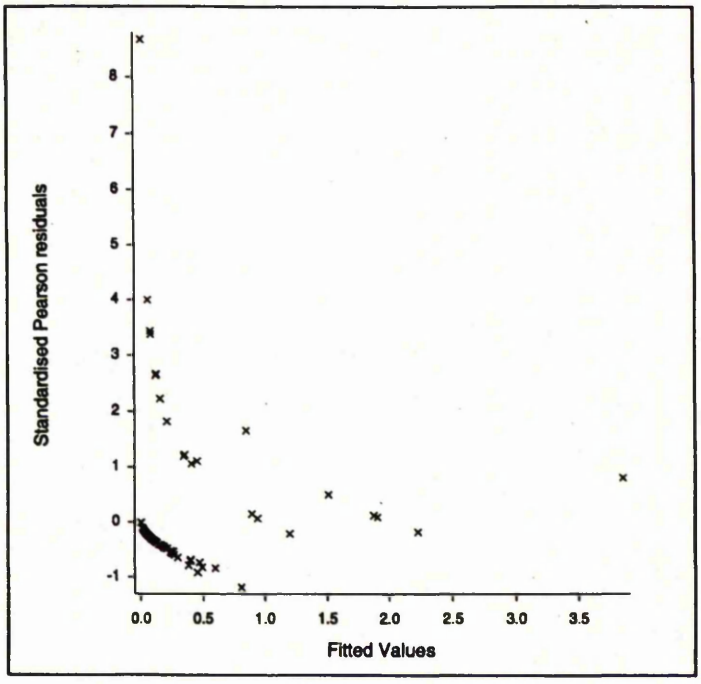
	estimate	s.e.	parameter
1	-3.902	0.7142	1
2	1.535	0.7948	SEX(2)
3	-7.804	22.79	F_YEAR(2)
4	1.001	0.8492	F_YEAR(3)
5	-0.1054	1.236	F_YEAR(4)
6	0.7450	1.016	F_YEAR(5)
7	-0.1924	1.236	F_YEAR(6)
8	6.588	22.81	SEX(2).F_YEAR(2)
9	-3.052	1.362	SEX(2).F_YEAR(3)
10	-2.049	1.631	SEX(2).F_YEAR(4)
11	-2.682	1.472	SEX(2).F_YEAR(5)
12	0.1085	1.366	SEX(2).F_YEAR(6)

Plot 4-4-1-7 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-1-5.

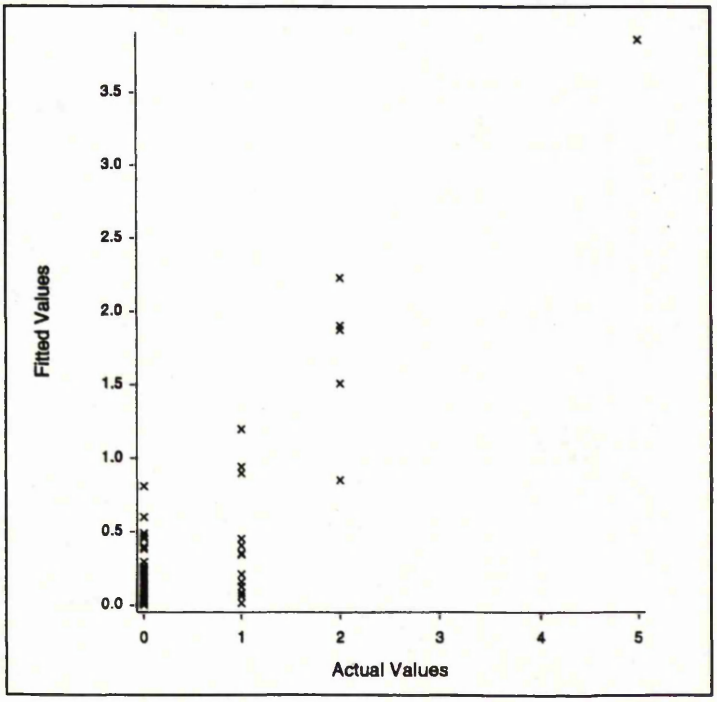
```
[-2.00,-1.00)   1
[-1.00, 0.00) 120 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.00, 1.00)   6 SS
[ 1.00, 2.00)   6 SS
[ 2.00, 3.00)   3 S
[ 3.00, 4.00)   3 S
[ 4.00, 5.00)   0
[ 5.00, 6.00)   0
[ 6.00, 7.00)   0
[ 7.00, 8.00)   0
[ 8.00, 9.00]   1
```

Mean = 0.013 S.D. = 1.76

Plot 4-4-1-8 : Scatter plot of standardised Pearson residual against fitted values for model of table 4-4-1-5.



Plot 4-4-1-9 : Scatter plot of fitted values against actual values for model of table 4-4-1-5.



4-4-2 : Modelling Probability Distribution Function of Later Asthma Admissions of Patients Whose First Asthma Admission is Type 2 :

Recall that first asthma admission of type 2 are actually those patients whose first asthma admissions to hospitals were recognised as "Emergency Admissions" and also asthma has been their first reason of hospitalisation. Note this group of patients could be probably named as the most seriously ill asthmatic patients (at time of first asthma admission) for whom we could expect to see more later asthma admissions than other patients with other type of first asthma admission. We concentrate on this type of first admission more than other types.

Table 4-4-2-1 shows the logistic model which is fitted to probability of "Not Returning to Hospital" in a 3 year horizon after first asthma admission. This model is fitted to later asthma admissions of those patients whose first asthma admissions are type 2. Table 4-4-2-1 indicates that among 4 factors age groups, sex, year of first admission and city, only 2 factors age group and sex and their interaction are significantly related to number of later asthma admissions. The scaled deviance of this logistic model which includes only two factors age group (at time of first admission) and sex and their interaction, is 199.1 with 174 degree of freedom. It implies the model is exactly fitted i.e. its scaled deviance is not significantly different from saturated model. This model suggests the probability of "Not Returning to Hospital", for the patients whose first asthma admission are type 2 (emergency first diagnosed as asthma) depends on sex, age of patient at time of first admission and the interaction

between age and sex. The model indicates that the probability of "Not Returning to Hospital" (number of later asthma admissions does not depend on either the year of first admission of asthmatic patients or the city which the patient lives in it.

Table 4-4-2-1 : Logistic model for probability of "Not returning to Hospital" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 2.

Final model : $C+\alpha(Age)+\beta(Sex)+\eta(Age.Sex)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age.Sex	17.09	2	P=.0002, Sig			
Year				9.168	5	P=.1025, N.S.
City				4.492	4	P=.3435, N.S.
Age.Year+Year				24.44	15	P=.0580, N.S.
Age.City+City				13.45	12	P=.3372, N.S.
Sex.Year+Year				11.20	10	P=.3422, N.S.
Sex.City+City				6.368	8	P=.6061, N.S.
Year.City+ Year+City				26.12	29	P=.6169, N.S.

scaled deviance = 199.1 residual df = 174 from 180 observations

	estimate	s.e.	parameter
1	0.4520	0.02944	1
2	1.002	0.09053	FAGE_GRP(2)
3	0.5991	0.05592	FAGE_GRP(3)
4	-0.09117	0.05062	SEX(2)
5	-0.4590	0.1178	FAGE_GRP(2).SEX(2)
6	0.01001	0.07897	FAGE_GRP(3).SEX(2)

scale parameter 1.000

The model indicates the probability of "Not Returning to Hospital" is greater for children (3-14 years old) and adults (more than 14 years old) than it is for babies (0-2 years old). Babies have the smallest probability of not returning to hospital among the 3 age groups. Note it implies children and adults are less likely than babies to return to hospital after first asthma

admission and also, comparing children and adults, children are less likely than adults to return to hospital. The model shows the probability of "Not Returning to Hospital" is smaller for females than for males. It suggests the probability of returning to hospital is greater for females than for males i.e. for those patients whose type of first admissions are type 2, females return to hospitals more frequently than males. For more discussion the reader could refer to second paragraph in section 4-4-1. The model indicates that there is some interaction effects between age groups 1 and 2 (babies and children) with sex and not between age groups 1 and 3 (babies and adults) with sex of patients. Hence the change in deviance is suggesting that the most important and effective factor in explaining the probability of not returning to hospitals, for those patients whose type of first asthma admissions are type 2, is the factor age group which shows age of patients at time of first admission. Note that large change in deviance implies that a large amount of variability of response variable is explained by the factor which currently was entered i.e. the factor has a great effect on response variable.

Plot 4-4-2-1 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-2-1.

```
[-3.500,-3.000)  1 S
[-3.000,-2.500)  1 S
[-2.500,-2.000)  4 SSSS
[-2.000,-1.500)  9 SSSSSSSSS
[-1.500,-1.000) 16 SSSSSSSSSSSSSSSS
[-1.000,-0.500) 24 SSSSSSSSSSSSSSSSSSSSSSSS
[-0.500, 0.000) 42 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.500) 24 SSSSSSSSSSSSSSSSSSSSSSSS
[ 0.500, 1.000) 28 SSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 1.000, 1.500) 21 SSSSSSSSSSSSSSSSSSSSS
[ 1.500, 2.000)  6 SSSSSS
[ 2.000, 2.500)  2 SS
[ 2.500, 3.000]  2 SS
```

Plots 4-4-2-1 to 4-4-2-3 are prepared to investigate how well the model of table 4-4-2-1 is fitted to probability of "Not Returning to Hospital". Plot 4-4-2-1 shows the histogram of standardised Pearson residuals for the above mentioned model. The mean and the standard deviation of standardised Pearson residuals are very close, respectively, to 0 and 1.

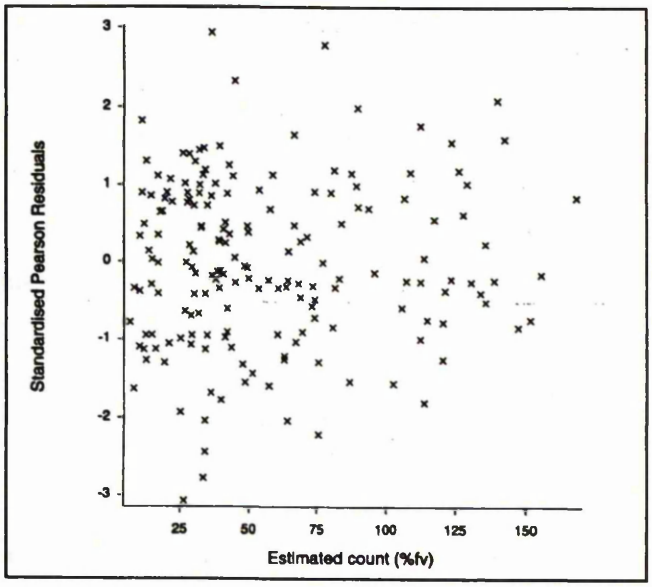
Plot 4-4-2-2 shows the plot of standardised Pearson residuals against the fitted values. The plot suggests no particular pattern in variance of standardised residuals. Note a very few residuals are out off 95% normal boundary for residuals. Plot 4-4-2-3 shows plot of fitted probabilities against actual probabilities. The plot suggests the models is very well fitted i.e. we could estimate the probability of "Not Returning to Hospital" sufficiently using the fitted model.

Table 4-4-2-2 shows the numbers of asthmatic patients (with first admissions of type 2) with 0, 1, 2, 3 and more than 3 later admissions in different sexes and age groups. Note that only two factors age and sex and their interaction terms were included in model of table 4-4-2-1.

Table 4-4-2-2: Numbers of patients (of first admissions type 2) with different number of later admissions in different sexes and age groups..

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
0-2 years	**Male**	2967	854	423	226	385	4855
	Female	1436	454	214	110	223	2437
	Total	4403	1308	637	336	608	7292
3-14 years	**Male**	719	102	33	16	17	887
	Female	869	195	71	31	55	1221
	Total	1588	297	104	47	72	2108
15 years and older	**Male**	1708	347	130	56	64	2305
	Female	2572	597	183	78	117	3547
	Total	4280	944	313	134	181	5852

Plot 4-4-2-2 : Scatter plot of standardised Pearson residual against fitted values for model of table 4-4-2-1.



Plot 4-4-2-3 : Scatter plot of fitted values against actual values for model of table 4-4-2-1.

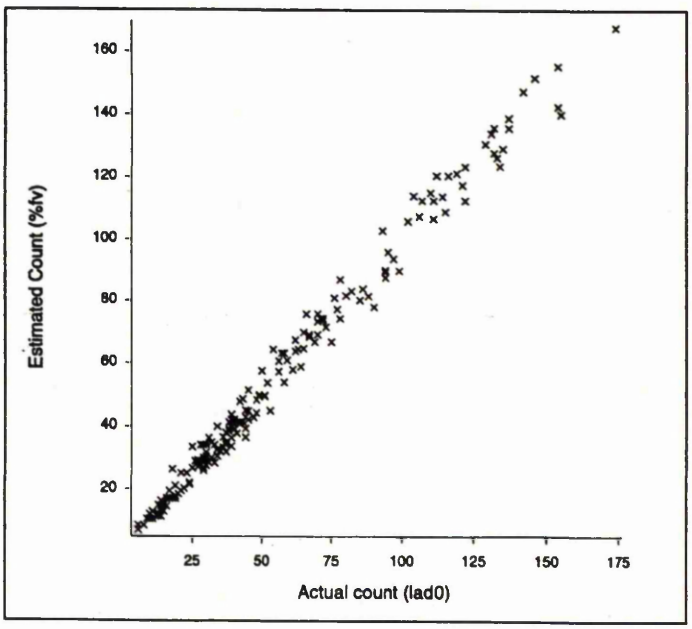


Table 4-4-2-3 shows the logistic model which is fitted to probability of "Having More Than Two Later Asthma Admissions" in a 3 year horizon after first asthma admission. The model is fitted to later asthma admissions of those patients whose first asthma admissions are type 2. This table indicates that the probability of "Having More Than Two Later Asthma Admissions" in a 3 year horizon after first admission, is significantly related to age group, sex and interaction between these two factors and is not related to year of first admission or the city in which the patient lives. The scaled deviance of the model is 208.5 with 174 degree of freedom. The model is exactly fitted i.e. its scaled deviance is not significantly different from the saturated model.

Table 4-4-2-3 : Logistic model for probability of "Having more than two later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 2.

Final model : $C+\alpha(Age)+\beta(Sex)+\eta(Age.Sex)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age.Sex	7.751	2	P=.0207, Sig			
Year				3.578	5	P=.6116, N.S.
City				7.228	4	P=.1243, N.S.
Age.Year+Year				14.62	15	P=.4791, N.S.
Age.City+City				16.3	12	P=.1779, N.S.
Sex.Year+Year				4.167	10	P=.9395, N.S.
Sex.City+City				9.789	8	P=.2658, N.S.
Year.City+ Year+City				33.49	29	P=.2584, N.S.

scaled deviance = 208.50 residual df = 174 from 180 observations.

	estimate	s.e.	parameter
1	-1.938	0.04327	1
2	-1.315	0.1826	FAGE_GRP(2)
3	-0.9637	0.1033	FAGE_GRP(3)
4	0.09471	0.07315	SEX(2)

```
      5       0.5787       0.2221       FAGE_GRP(2).SEX(2)
      6     -0.03714       0.1399       FAGE_GRP(3).SEX(2)
scale parameter 1.000
```

Model of table 4-4-2-3 shows the age of patient at time of first admission is the most important and effective factor that effects on number of later asthma admissions. The model suggests that the probability of "Having More Than Two Later Asthma Admissions" is smaller for children (3-14 years old) and adults (more than 14 years) than it is for babies (0-2 years old). Comparing children and adults, the model suggests children have smaller chance of "Having More Than Two Later Asthma Admissions" than adults. It implies the babies, whose first admission is type 2, are more likely than children and adults to have more than two later admissions and also adults are more likely than children to have more than two later asthma admissions. The model of table 4-4-2-3 suggests also that when the interaction between age group and sex are considered then the main effect of sex on number of later admissions is not significant.

Plots 4-4-2-4 to 4-4-2-6 are prepared to investigate how well the model of table 4-4-2-3 is fitted. Plot 4-4-2-4 shows the histogram of standardised Pearson residuals of the fitted model . Plot 4-4-2-5 shows the scatter plot of standardised Pearson residuals against the fitted values. This plot suggests some pattern in residuals' variance for small number of later asthma admissions but there is no pattern in residuals' variance for later asthma admissions more than 10. For this number of later asthma admissions or more than it, a few later asthma admissions are out of 95% normal boundary for standardised residuals. Plot 4-4-2-6 shows the plot of fitted probabilities against the actual probabilities of "Having More Than Two Later Asthma Admissions". Plots 4-4-2-5 and 4-4-2-6 together indicate that the model of table 4-4-2-3 is fairly well fitted to probability of "Having More Than Two Later Asthma Admissions".

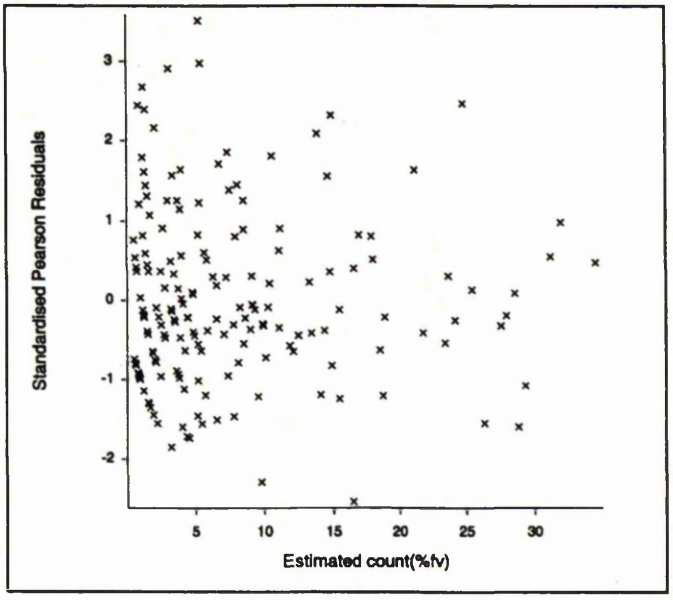
Plot 4-4-2-4 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-2-3.

```
[-3.000,-2.400)  1 S
[-2.400,-1.800)  2 SS
[-1.800,-1.200) 17 SSSSSSSSSSSSSSSSS
[-1.200,-0.600) 32 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.600, 0.000) 50 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.600) 33 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.600, 1.200) 17 SSSSSSSSSSSSSSSSS
[ 1.200, 1.800) 16 SSSSSSSSSSSSSSSS
[ 1.800, 2.400)  6 SSSSSS
[ 2.400, 3.000)  5 SSSSS
[ 3.000, 3.600)  1 S
[ 3.600, 4.200)  0
[ 4.200, 4.800]  0
```

Since same factors and interaction terms are included in model 4-4-2-3 as in model 4-4-2-1 therefore we refer reader to table 4-4-2-2 to see the descriptive data of later admissions in different combinations of included factors.

Table 4-4-2-4 shows the logistic model which is fitted to probability of "Having More Than Three Later Asthma Admissions" in a 3 year horizon after first asthma admission, for those patients whose first asthma admissions are type 2. Once again the model suggests the probability of "Having More Than Three Later Asthma Admissions" is only related to two factors age group and sex and their interaction terms. The scaled deviance of the model is 212.17 with 174 degree of freedom which is very close to be not significantly different from the scaled deviance of the saturated model. The model suggests similar results as the logistic models which were fitted to probability of "Not Returning to Hospital" or to the probability of "Having More Than Two Later Asthma Admissions".

Plot 4-4-2-5 : Scatter plot of standardised Pearson residual against fitted values for model of table 4-4-2-3.



Plot 4-4-2-6 : Scatter plot of fitted values against actual values for model of table 4-4-2-3.

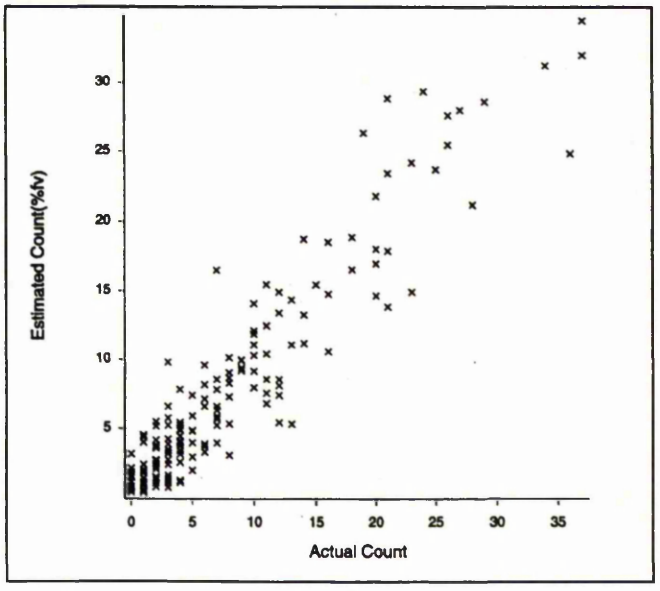


Table 4-4-2-4 : Logistic model for probability of "Having more than three later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 2.

Final model : C+α(Age)+β(Sex)+ η(Age.Sex).

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age.Sex	6.704	2	P=.0350, Sig			
Year				2.628	5	P=.7571, N.S.
City				5.611	4	P=.2301, N.S.
Age.Year+Year				14.96	15	P=.4543, N.S.
Age.City+City				15.64	12	P=.2083, N.S.
Sex.Year+Year				7.581	10	P=.6697, N.S.
Sex.City+City				8.025	8	P=.4310, N.S.
Year.City+ Year+City				23.01	29	P=.7761, N.S.

scaled deviance = 212.17 residual df = 174 from 180 observations.

	estimate	s.e.	parameter
1	-2.452	0.05311	1
2	-1.483	0.2504	FAGE_GRP(2)
3	-1.104	0.1374	FAGE_GRP(3)
4	0.1565	0.08807	SEX(2)
5	0.7248	0.2944	FAGE_GRP(2).SEX(2)
6	0.02114	0.1807	FAGE_GRP(3).SEX(2)

scale parameter 1.000

Plots 4-4-2-7 to 4-4-2-9 are prepared to investigate the goodness of fit of the model of table 4-4-2-4. Plot 4-4-2-7 shows the histogram of standardised Pearson residuals and indicates the mean and residuals' variance are very close to, respectively, 0 and 1. Plot 4-4-2-8 shows the scatter plot of standardised Pearson residuals against the fitted values. The plot indicates that for later asthma admissions greater than 10, there is no pattern in residuals' variance. this plot together with plot 4-4-2-9 suggest the model of table 4-4-2-4 is not badly fitted.

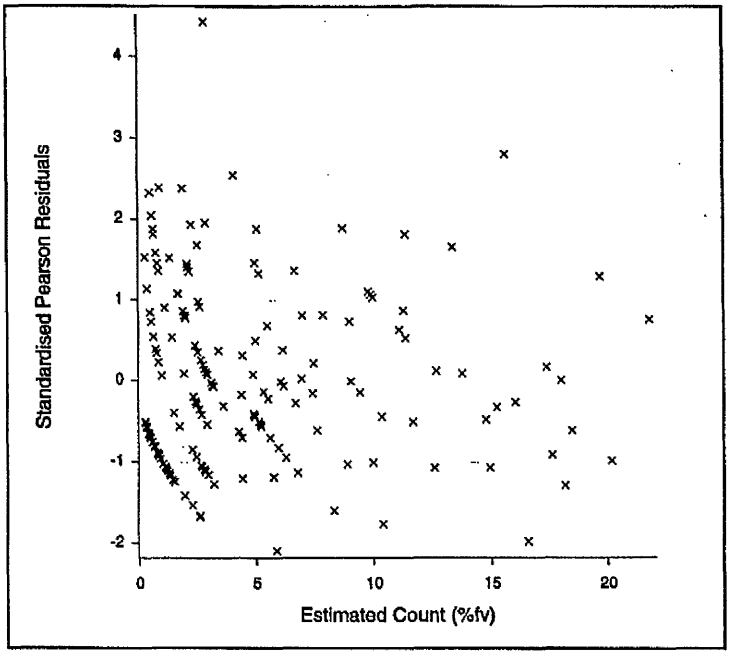
Plot 4-4-2-7 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-2-4.

```
[-2.400,-1.800)  2 SS
[-1.800,-1.200) 11 SSSSSSSSSSS
[-1.200,-0.600) 46 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.600, 0.000) 42 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.600) 29 SSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.600, 1.200) 21 SSSSSSSSSSSSSSSSSSSS
[ 1.200, 1.800) 15 SSSSSSSSSSSSSSS
[ 1.800, 2.400) 11 SSSSSSSSSSS
[ 2.400, 3.000)  2 SS
[ 3.000, 3.600)  0
[ 3.600, 4.200)  0
[ 4.200, 4.800)  1 S
[ 4.800, 5.400]  0
```

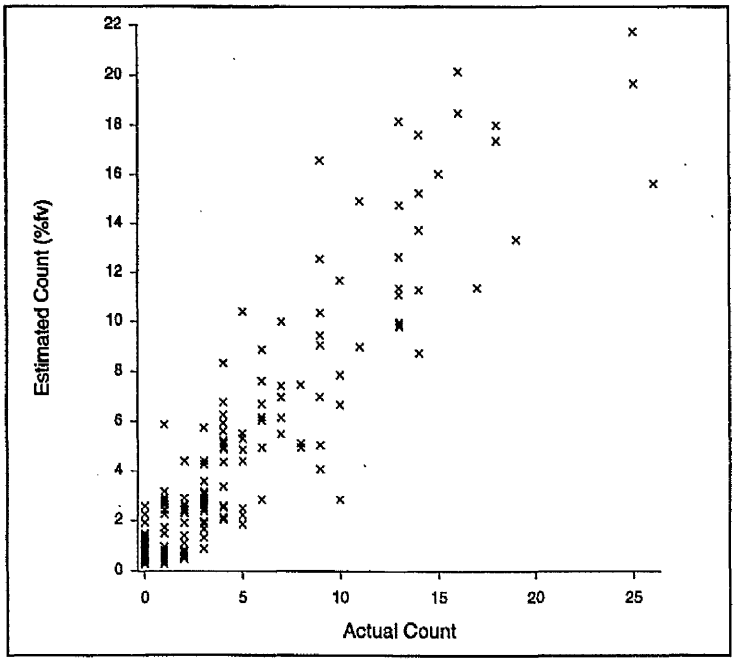
Mean = -0.0162 S.D. = 1.083

Since same factors and interaction terms are included in model 4-4-2-4 as in models 4-4-2-1 and 4-4-2-3 therefore we refer reader to table 4-4-2-2 to see the descriptive data of later admissions in different combinations of included factors.

Plot 4-4-2-8 : Scatter plot of standardised Pearson residual against fitted values for model of table 4-4-2-4.



Plot 4-4-2-9 : Scatter plot of fitted values against actual values for model of table 4-4-2-4.



4-4-3 : Modelling Probability Distribution Function of Later Asthma Admissions of Patients Whose First Asthma Admission is Type 3 :

Here we intend to model different points of probability distribution function of later asthma admissions of those asthmatic patients whose first asthma admissions are type 3, using 4 factors age group, sex, year of first admission and city. Recall the first asthma admission of type 3 are first asthma admission of those patients whose second reason of hospitalisation was asthma and have been admitted as non emergency cases. The events, same as in sections 4-4-2-1 and 4-4-2-2, are (1) the number of later asthma admissions=0, (2) number of later asthma admissions >2 and number of later asthma admissions > 3.

Tables 4-4-3-1, 4-4-3-2 and 4-4-3-3 show the logistic models which are fitted, respectively, to probability of "Not Returning to Hospital", "Having More Than Two Later Asthma Admissions" and "Having More Than Three Later Asthma Admissions" in a 3 year horizon after first asthma admission for patients with first asthma admission of type 3. None of four previously mentioned factors is significantly related to any of these 3 mentioned probabilities. It suggests the probability distribution function of later asthma admissions of those patients whose first asthma admissions are type 3 does not depend on factors age group, sex, year of first admission or city.

Table 4-4-3-1 : Logistic model for probability of "Not returning to hospital" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 3.

Final model includes only constant term

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age				4.432	2	P=.1090, N.S.
Sex				0.436	1	P=.5091, N.S.
Year				8.651	5	P=.1238, N.S.
City				8.576	4	P=.0726, N.S.
Age.Sex+ Age+Sex				6.034	5	P=.3029, N.S.
Age.Year+ Age+Year				23.15	17	P=.1444, N.S.
Age.City+ Age+City				18.82	14	P=.1719, N.S.
Sex.Year+ Sex+Year				17.91	11	P=.0837, N.S.
Sex.City+ Sex+City				12.16	9	P=.2044, N.S.
Year.City+ Year+City				40.55	29	P=.0753, N.S.

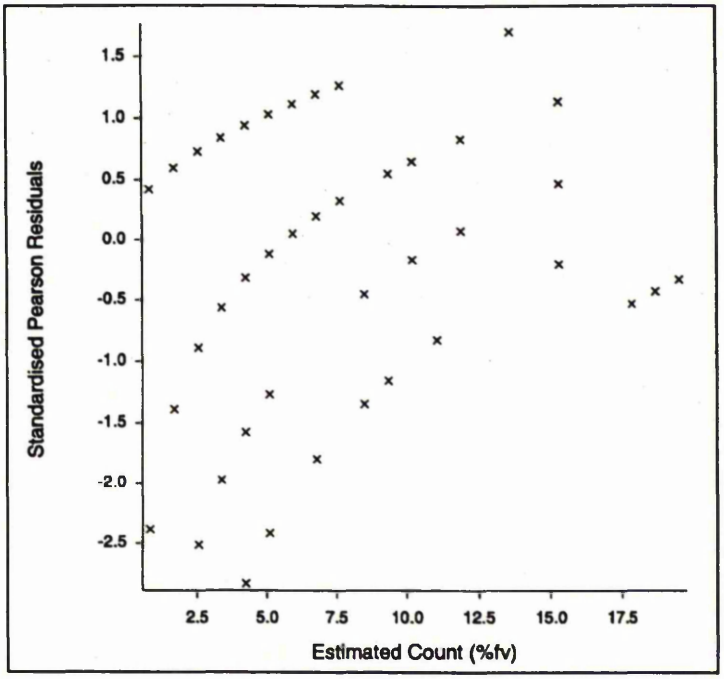
scaled deviance = 163.76 residual df = 149 from 150 observations.

```
            estimate        s.e.       parameter
1        1.736       0.1077       1

scale parameter 1.000
```

Plot 4-4-3-1 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-3-1.

```
[-3.000,-2.500)  2 SS
[-2.500,-2.000)  9 SSSSSSSSS
[-2.000,-1.500)  7 SSSSSSS
[-1.500,-1.000) 10 SSSSSSSSSS
[-1.000,-0.500)  9 SSSSSSSSS
[-0.500, 0.000) 11 SSSSSSSSSSS
[ 0.000, 0.500) 41 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.500, 1.000) 50 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 1.000, 1.500) 10 SSSSSSSSSS
[ 1.500, 2.000)  1 S
[ 2.000, 2.500)  0
[ 2.500, 3.000]  0
                        Mean = 0.009  S.D. = 1.036
```

Plot 4-4-3-2 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-3-1.



Plot 4-4-3-3 : Scatter plot of fitted values against actual values for model of table 4-4-3-1.

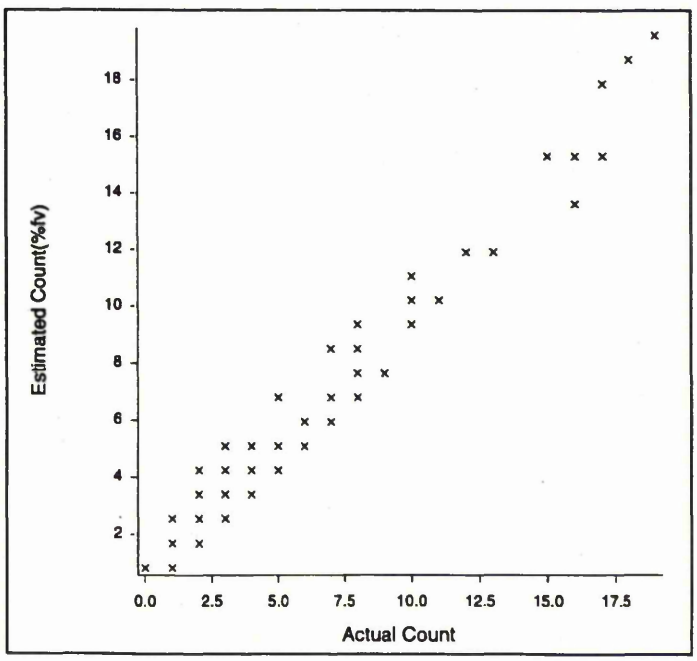


Table 4-4-3-2 : Logistic model for probability of "Having More than two later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 3.

Final model includes only constant term

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age				0.177	2	P=.9153, N.S.
Sex				2.43	1	P=.1190, N.S.
Year				4.775	5	P=.4440, N.S.
City				2.067	4	P=.7234, N.S.
Age.Sex+ Age+Sex				6.928	5	P=.5561, N.S.
Age.Year+ Age+Year				18.56	17	P=.3544, N.S.
Age.City+ Age+City				10.87	14	P=.6962, N.S.
Sex.Year+ Sex+Year				13.49	11	P=.2625, N.S.
Sex.City+ Sex+City				12.73	9	P=.1752, N.S.
Year.City+ Year+City				26.93	29	P=.5755, N.S.

scaled deviance = 71.9 residual df = 149 from 150 observations.

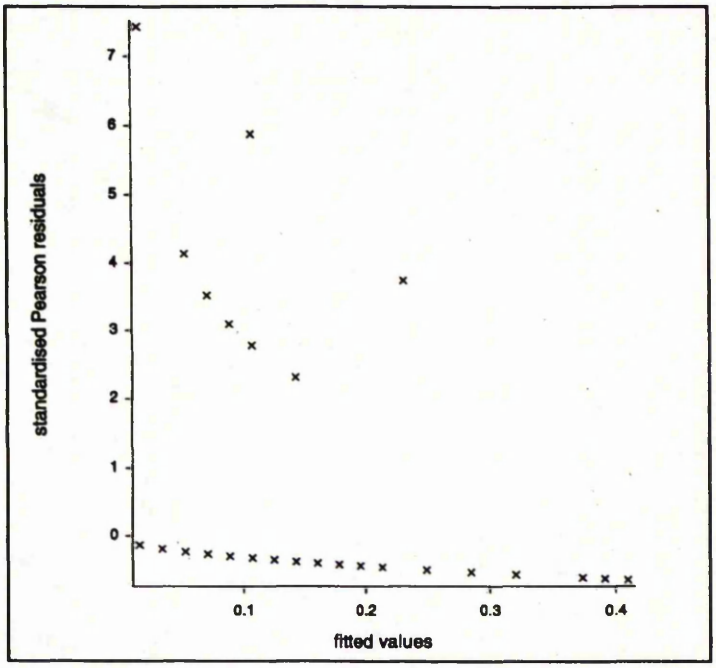
```
      estimate       s.e.     parameter
1      -4.010       0.2910       1

scale parameter 1.000
```

Plot 4-4-3-4 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-3-2.

```
[-0.800, 0.000) 140 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.800)   0
[ 0.800, 1.600)   0
[ 1.600, 2.400)   1
[ 2.400, 3.200)   3 S
[ 3.200, 4.000)   2 S
[ 4.000, 4.800)   1
[ 4.800, 5.600)   0
[ 5.600, 6.400)   1
[ 6.400, 7.200)   0
[ 7.200, 8.000)   2 S
[ 8.000, 8.800]   0
```

Mean = 0.05 S.D. = 1.25

Plot 4-4-3-5 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-3-2.



Plot 4-4-3-6 : Scatter plot of fitted values against actual values for model of table 4-4-3-2.

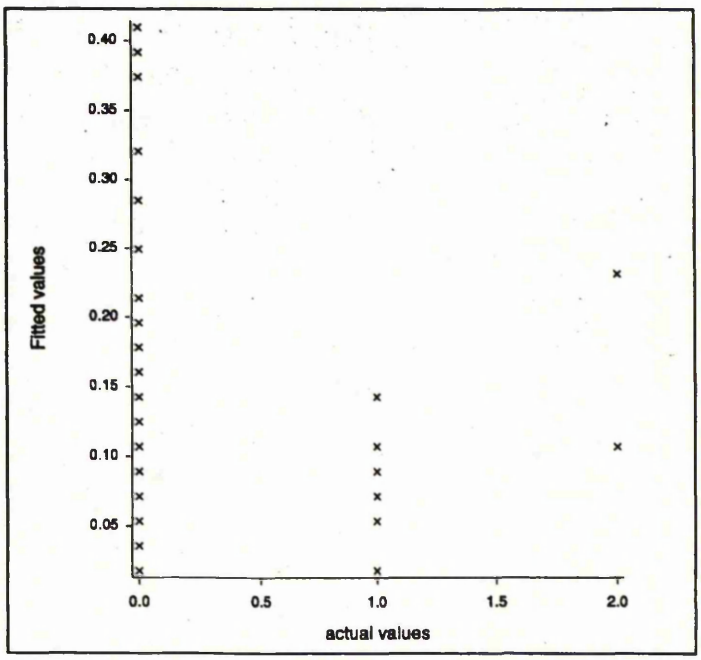


Table 4-4-3-3 : Logistic model for probability of "Having More than three later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 3.

Final model includes only constant term

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age				0.468	2	P=.7914, N.S.
Sex				3.11	1	P=.0778, N.S.
Year				5.597	5	P=.3474, N.S.
City				1.399	4	P=.8444, N.S.
Age.Sex+ Age+Sex				8.641	5	P=.1243, N.S.
Age.Year+ Age+Year				18.08	17	P=.3838, N.S.
Age.City+ Age+City				12.57	14	P=.5606, N.S.
Sex.Year+ Sex+Year				13.96	11	P=.2352, N.S.
Sex.City+ Sex+City				13.39	9	P=.1457, N.S.
Year.City+ Year+City				23.33	29	P=.7612, N.S.

scaled deviance = 55.367 residual df = 149 from 150 observations.

	estimate	s.e.	parameter
1	-4.422	0.3543	1

scale parameter 1.000

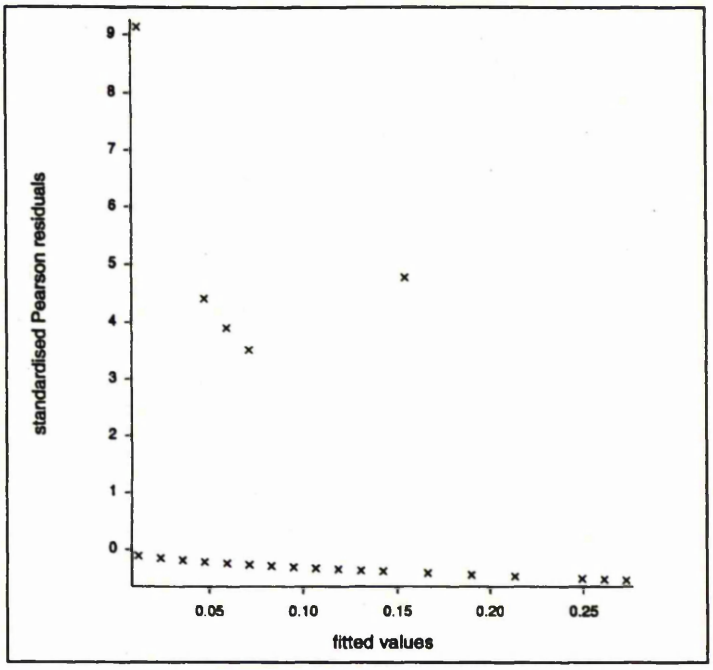
Plot 4-4-3-7 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-3-3.

[-1.00, 0.00) 143 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.00, 1.00) 0
[1.00, 2.00) 0
[2.00, 3.00) 0
[3.00, 4.00) 3 S
[4.00, 5.00) 2 S
[5.00, 6.00) 0
[6.00, 7.00) 0
[7.00, 8.00) 0
[8.00, 9.00) 0
[9.00, 10.00) 2 S
[10.00, 11.00] 0

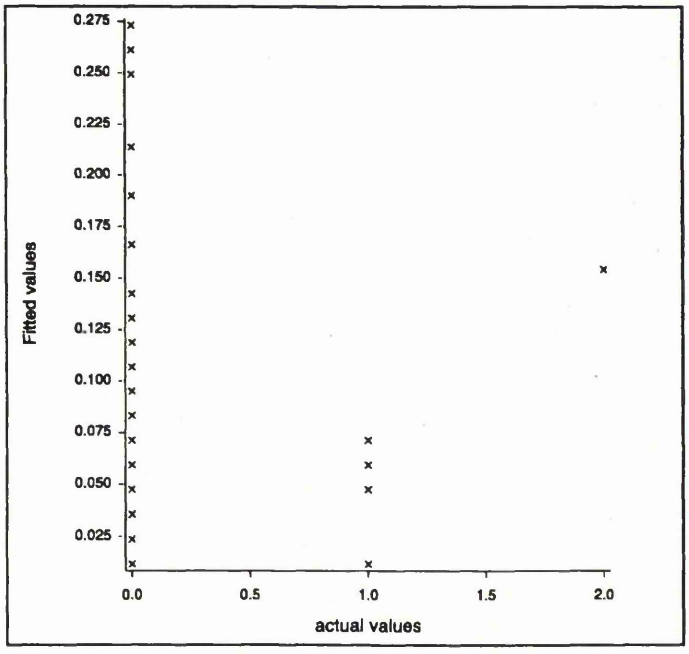
Mean = 0.056 S.D. = 1.311

Since none of factors age, sex, year and city are related to numbers of patients (with first admissions of type 3) with 0, 1, 2, 3 and more than 3 later admissions therefore no table was prepared to show these numbers. We only mention that there were 674 patients with first admission of type 3. Of these 573, 70, 19, 8 and 3 patients have, respectively, 0, 1, 2, 3 and more than 3 later admissions.

Plot 4-4-3-8 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-3-3.



Plot 4-4-3-9 : Scatter plot of fitted values against actual values for model of table 4-4-3-3.



4-4-4 : Modelling Probability Distribution Function of Later Asthma Admissions of Patients Whose First Asthma Admission is Type 4 :

In this section we are going to fit 3 different logistic models to 3 particular points of probability distribution function of later asthma admissions of those patients whose first asthma admissions are type 4. As before we consider later asthma admissions in a 3 year horizon after first asthma admission. Before introducing the models, we remind the reader that first asthma admissions of type 4 are first asthma admissions of those asthmatic patients whose asthma has been their second reason of hospitalisation and have been admitted as emergency admissions.

Table 4-4-4-1 shows the logistic model which is fitted to probability of "Not Returning to Hospital" in a 3 year horizon after first asthma admission for patients with first asthma admissions of type 4. The table indicates the probability of "Not Returning to Hospital" depends on two factors "age group" and "sex" and also to interaction between two factors "year" and "city". Note it is the reason that the final model includes factors "Age group", "sex", "Year", "City" and the interaction between "year" and "city". The model shows the mentioned probability depends on all four factors as well as on interaction between "year" and "city". The scaled deviance of the model is 178.12 with 139 degree of freedom which indicates the scaled deviance of the model is significantly different from the saturated model i.e. the model is not exactly fitted. Later we will investigate the goodness of fit of the model.

Table 4-4-4-1 : Logistic model for probability of "Not returning to hospital" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 4.

Final model : $C+\alpha(Age)+\beta(Sex)+\gamma(Year)+\eta(City)+\lambda(Year.City)$.

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age	34.03	2	P<.0001, Sig.			
Sex	3.92	1	P=.0477, Sig.			
Year.City	36.20	20	P=.0146, Sig.			
Age.Sex				0.976	2	P=.6139, N.S.
Age.Year				7.472	10	P=.6803, N.S.
Age.City				8.398	8	P=.9070, N.S.
Sex.Year				4.827	5	P=.4374, N.S.
Sex.City				3.788	4	P=.4355, N.S.

scaled deviance = 178.12 residual df = 139 from 172 observations.

	estimate	s.e.	parameter
1	0.4461	0.4132	1
2	0.7194	0.2178	FAGE_GRP(2)
3	0.7754	0.1336	FAGE_GRP(3)
4	-0.2350	0.1188	SEX(2)
5	0.4746	0.5531	F_YEAR(2)
6	0.03034	0.5422	F_YEAR(3)
7	0.3591	0.5305	F_YEAR(4)
8	0.9556	0.6722	F_YEAR(5)
9	0.07747	0.5677	F_YEAR(6)
10	0.1282	0.4786	F_CITY(2)
11	0.5292	0.4742	F_CITY(3)
12	-0.4198	0.7218	F_CITY(4)
13	0.1317	0.5053	F_CITY(5)
14	-0.4289	0.6590	F_YEAR(2).F_CITY(2)
15	-1.136	0.6482	F_YEAR(2).F_CITY(3)
16	0.1546	0.9293	F_YEAR(2).F_CITY(4)
17	-0.5047	0.6780	F_YEAR(2).F_CITY(5)
18	-0.4153	0.6478	F_YEAR(3).F_CITY(2)
19	0.1542	0.6820	F_YEAR(3).F_CITY(3)
20	0.3396	0.9468	F_YEAR(3).F_CITY(4)
21	1.942	0.8529	F_YEAR(3).F_CITY(5)
22	-0.5249	0.6515	F_YEAR(4).F_CITY(2)
23	-0.6330	0.6471	F_YEAR(4).F_CITY(3)
24	0.6998	0.8964	F_YEAR(4).F_CITY(4)
25	-0.03394	0.6641	F_YEAR(4).F_CITY(5)
26	-0.4174	0.7717	F_YEAR(5).F_CITY(2)
27	-1.201	0.7633	F_YEAR(5).F_CITY(3)
28	1.135	1.163	F_YEAR(5).F_CITY(4)
29	-0.8198	0.7840	F_YEAR(5).F_CITY(5)
30	0.1241	0.6742	F_YEAR(6).F_CITY(2)
31	-0.2058	0.6791	F_YEAR(6).F_CITY(3)

```
    32        1.541        1.030       F_YEAR(6).F_CITY(4)
    33       0.6711       0.7028       F_YEAR(6).F_CITY(5)
scale parameter 1.000
```

The model of table 4-4-4-1 suggests that the probability of "Not Returning to Hospital" is greater for children (3-14 years old) and adults (more than 14 years) than babies (0-2 years old). It implies, same as the previous logistic models in sections 4-4-1 to 4-4-3, that babies are more likely than children and adults to return to hospital after first asthma admission. The model implies also the probability of "Not Returning to Hospital" for females is smaller than males i.e. females return to hospital more frequently than females after first admission. The model also suggests that the mentioned probability is different in different cities and different cohorts of first asthma admissions.

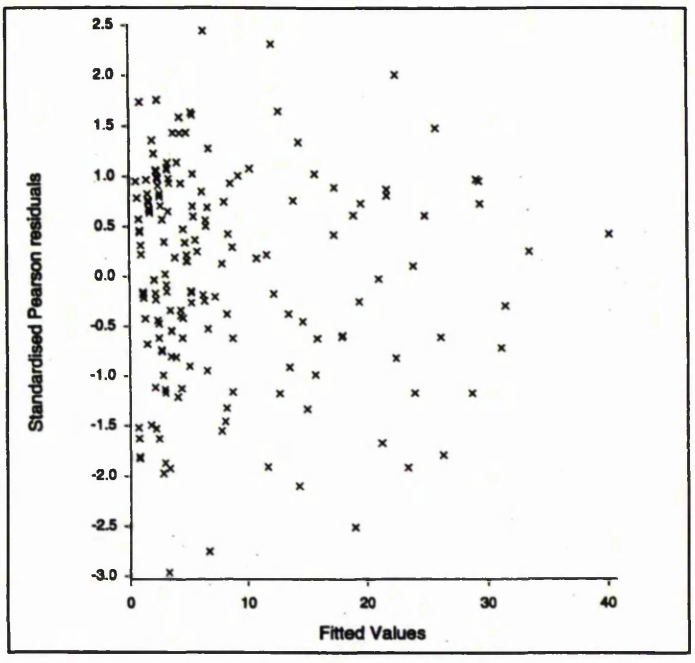
Plots 4-4-4-1 to 4-4-4-3 are prepared to investigate the goodness of fit of the model of table 4-4-4-1. Plot 4-4-4-1 shows the histogram of standardised Pearson residuals for the model of table 4-4-4-1 which contains constant term plus all four factors. The mean and standard deviation of the standardised residuals are, respectively, very close to 0 and 1. Plot 4-4-4-2 shows the scatter plot of standardised Pearson residuals against the fitted probabilities. The plot

Plot 4-4-4-1 : Histogram of standardised Pearson Residuals
for logistic model of table 4-4-4-1.

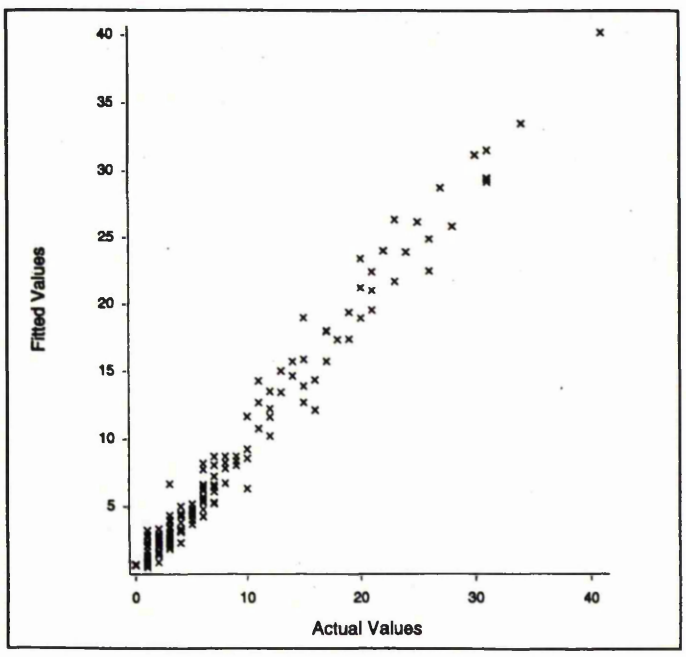
```
[-3.000,-2.500)  3 SSS
[-2.500,-2.000)  1 S
[-2.000,-1.500) 14 SSSSSSSSSSSSSS
[-1.500,-1.000) 13 SSSSSSSSSSSSS
[-1.000,-0.500) 22 SSSSSSSSSSSSSSSSSSSSS
[-0.500, 0.000) 28 SSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 0.000, 0.500) 23 SSSSSSSSSSSSSSSSSSSSS
[ 0.500, 1.000) 41 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[ 1.000, 1.500) 18 SSSSSSSSSSSSSSSSS
[ 1.500, 2.000)  6 SSSSSS
[ 2.000, 2.500)  3 SSS
[ 2.500, 3.000)  0
[ 3.000, 3.500]  0
  0.0174
```

Mean = 0.017 S.D. =1.058

Plot 4-4-4-2 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-4-1.



Plot 4-4-4-3 : Scatter plot of fitted values against actual values for model of table 4-4-4-1.



indicates no pattern for residuals. It implies assumption of having the constant residuals' variance is valid. Plot 4-4-4-3 shows the scatter plot of fitted probabilities against the actual ones. This plot indicates the model is fairly good for prediction. Plots 4-4-4-2 and 4-4-4-3 imply together that the model, in spite of having significantly different scaled deviance from the saturated model, is fairly well fitted.

Each of tables 4-4-4-2 to 4-4-4-16 show the numbers of asthmatic patients (with first admissions of type 2) with 0, 1, 2, 3 and more than 3 later admissions in different sexes and cohorts of first admissions in a particular age group and city. Note that all factors age, sex, year and city were included in model of table 4-4-4-1.

Table 4-4-4-2: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For babies age group (0-2 years old), Aberdeen.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	6	0	0	0	1	7
	Female	1	1	0	0	0	2
	Total	7	1	0	0	1	9
1985	**Male**	6	2	0	0	0	8
	Female	2	1	0	1	0	4
	Total	8	3	0	1	0	12
1986	**Male**	6	2	0	0	1	9
	Female	1	0	0	0	1	2
	Total	7	2	0	0	2	11
1987	**Male**	6	3	0	0	0	9
	Female	1	1	0	0	0	2
	Total	7	4	0	0	0	11
1988	**Male**	6	0	0	0	0	6
	Female	1	0	0	0	0	1
	Total	7	0	0	0	0	7
1989	**Male**	4	1	0	1	2	8
	Female	1	1	0	0	0	2
	Total	5	2	0	1	2	10

Table 4-4-4-3: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For babies age group (0-2 years old), Edinburgh.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	12	2	0	0	2	16
	Female	4	0	0	0	0	4
	Total	16	2	0	0	2	20
1985	**Male**	5	2	0	0	1	8
	Female	3	1	0	0	1	5
	Total	8	3	0	0	2	13
1986	**Male**	6	3	3	3	0	15
	Female	3	3	1	0	0	7
	Total	9	6	4	3	0	22
1987	**Male**	5	1	1	1	0	8
	Female	4	2	0	0	0	6
	Total	9	3	1	1	0	14
1988	**Male**	11	5	2	0	1	19
	Female	3	0	1	0	1	5
	Total	14	5	3	0	2	24
1989	**Male**	12	3	2	0	0	17
	Female	3	0	0	0	0	3
	Total	15	3	2	0	0	20

Table 4-4-4-4: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For babies age group (0-2 years old), Glasgow.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	7	2	0	0	1	10
	Female	3	0	0	0	0	3
	Total	10	2	0	0	1	13
1985	**Male**	10	0	1	0	0	11
	Female	1	0	1	0	2	4
	Total	11	0	2	0	2	15
1986	**Male**	7	0	0	0	0	7
	Female	1	1	1	0	0	3
	Total	8	1	1	0	0	10
1987	**Male**	3	3	1	1	2	10
	Female	6	1	0	0	0	7
	Total	9	4	1	1	2	17
1988	**Male**	16	1	0	1	0	18
	Female	3	2	1	0	1	7
	Total	19	3	1	1	1	25
1989	**Male**	9	1	1	1	0	12
	Female	3	1	1	0	1	6
	Total	12	2	2	1	1	18

Table 4-4-4-5: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For babies age group (0-2 years old), Motherwell.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	2	1	0	1	0	4
	Female	2	0	0	0	0	2
	Total	4	1	0	1	0	6
1985	**Male**	2	0	1	0	1	4
	Female	2	1	0	0	1	4
	Total	4	1	1	0	2	8
1986	**Male**	1	2	0	1	0	4
	Female	1	0	0	0	0	1
	Total	2	2	0	1	0	5
1987	**Male**	13	3	1	0	1	18
	Female	3	2	0	0	0	5
	Total	16	5	1	0	1	23
1988	**Male**	6	0	0	0	0	6
	Female	3	0	0	0	1	4
	Total	9	0	0	0	1	10
1989	**Male**	3	0	0	0	0	3
	Female	4	0	0	0	0	4
	Total	7	0	0	0	0	7

Table 4-4-4-6: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For babies age group (0-2 years old), Pooled* city.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	4	1	0	1	1	7
	Female	1	3	0	1	0	5
	Total	5	4	0	2	1	12
1985	**Male**	6	1	1	1	1	10
	Female	5	2	2	0	0	9
	Total	11	3	3	1	1	19
1986	**Male**	10	0	0	0	0	10
	Female	3	0	0	0	0	3
	Total	13	0	0	0	0	13
1987	**Male**	12	7	0	0	0	19
	Female	10	0	2	1	0	13
	Total	22	7	2	1	0	32
1988	**Male**	7	2	3	0	1	13
	Female	3	2	0	0	0	5
	Total	10	4	3	0	1	18
1989	**Male**	13	3	2	0	1	19
	Female	7	0	0	0	0	7
	Total	20	3	2	0	1	26

*pooled city includes Dundee, Kilmarnock and Paisley.

Table 4-4-4-7: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For second age group (3-14 years old), Aberdeen.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	0	1	0	0	0	1
	Female	0	1	0	0	0	1
	Total	0	2	0	0	0	2
1985	**Male**	2	0	1	0	1	4
	Female	2	0	0	1	0	3
	Total	4	0	1	1	1	7
1986	**Male**	3	0	0	0	0	3
	Female	2	1	0	0	0	3
	Total	5	1	0	0	0	6
1987	**Male**	4	0	0	0	0	4
	Female	2	0	0	0	0	2
	Total	6	0	0	0	0	6
1988	**Male**	0	0	0	0	0	0
	Female	0	0	0	0	0	0
	Total	0	0	0	0	0	0
1989	**Male**	3	0	0	0	0	3
	Female	2	2	0	0	0	4
	Total	5	2	0	0	0	7

Table 4-4-4-8: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For second age group (3-14 years old), Edinburgh.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	4	0	0	0	0	4
	Female	3	0	0	0	0	3
	Total	7	0	0	0	0	7
1985	**Male**	3	0	0	0	0	3
	Female	2	0	0	0	0	2
	Total	5	0	0	0	0	5
1986	**Male**	1	0	0	0	1	2
	Female	0	0	0	0	0	0
	Total	1	0	0	0	0	1
1987	**Male**	5	1	0	0	0	6
	Female	2	0	0	0	1	3
	Total	7	1	0	0	1	9
1988	**Male**	3	0	0	0	0	3
	Female	3	0	0	0	0	3
	Total	6	0	0	0	0	6
1989	**Male**	2	0	0	0	0	2
	Female	5	1	0	0	0	6
	Total	7	1	0	0	0	8

Table 4-4-4-9: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For second age group (3-14 years old), Glasgow.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	8	0	0	0	0	8
	Female	1	3	0	0	0	4
	Total	9	3	0	0	0	12
1985	Male	6	3	0	0	0	9
	Female	1	3	0	0	0	4
	Total	7	6	0	0	0	13
1986	Male	5	1	0	0	0	6
	Female	1	0	0	0	0	1
	Total	6	1	0	0	0	7
1987	Male	3	2	0	0	0	5
	Female	4	0	1	0	0	5
	Total	7	2	1	0	0	10
1988	Male	5	0	1	0	0	6
	Female	2	0	0	1	0	3
	Total	7	0	1	1	0	9
1989	Male	1	0	0	0	0	1
	Female	4	0	0	0	0	4
	Total	5	0	0	0	0	5

Table 4-4-4-10: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For second age group (3-14 years old), Motherwell.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	0	1	0	0	0	1
	Female	0	0	0	0	0	0
	Total	0	1	0	0	0	1
1985	Male	2	0	0	0	0	2
	Female	0	1	0	0	0	1
	Total	2	1	0	0	0	3
1986	Male	0	0	0	0	0	0
	Female	2	0	0	0	0	2
	Total	2	0	0	0	0	2
1987	Male	1	1	0	0	0	2
	Female	2	0	0	0	0	2
	Total	3	1	0	0	0	4
1988	Male	0	0	0	0	0	0
	Female	0	0	0	0	0	0
	Total	0	0	0	0	0	0
1989	Male	1	0	0	0	0	1
	Female	0	0	0	0	0	0
	Total	1	0	0	0	0	1

Table 4-4-4-11: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For second age group (3-14 years old), Pooled* city.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	2	0	0	0	0	2
	Female	2	1	1	0	0	4
	Total	4	1	1	0	0	6
1985	Male	3	0	0	0	1	4
	Female	3	0	0	0	0	3
	Total	6	0	0	0	1	7
1986	Male	3	0	0	0	0	3
	Female	1	0	0	0	0	1
	Total	4	0	0	0	0	4
1987	Male	2	0	0	0	0	2
	Female	5	1	0	0	0	6
	Total	7	1	0	0	0	8
1988	Male	5	0	0	0	0	5
	Female	3	0	0	0	0	3
	Total	8	0	0	0	0	8
1989	Male	4	1	0	0	0	5
	Female	4	1	0	0	0	5
	Total	8	2	0	0	0	10

*pooled city includes Dundee, Kilmarnock and Paisley.

Table 4-4-4-12: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For third age group (15 years and more), Aberdeen.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	6	1	0	0	0	7
	Female	8	3	1	0	0	12
	Total	14	4	1	0	0	19
1985	Male	16	1	0	0	0	17
	Female	7	1	0	0	0	8
	Total	23	2	0	0	0	25
1986	Male	6	2	1	0	1	10
	Female	9	1	1	0	0	11
	Total	15	3	2	0	1	21
1987	Male	11	2	0	0	0	13
	Female	15	2	1	1	1	20
	Total	26	4	1	1	1	33
1988	Male	10	2	0	1	0	13
	Female	9	0	1	0	0	10
	Total	19	2	1	1	0	23
1989	Male	8	2	0	0	0	10
	Female	5	0	0	0	0	5
	Total	13	2	0	0	0	15

Table 4-4-4-13: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For third age group (15 years and more), Edinburgh.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	11	3	1	0	1	16
	Female	23	5	2	3	2	35
	Total	34	8	3	3	3	51
1985	**Male**	21	5	1	1	0	28
	Female	34	8	1	0	1	44
	Total	55	13	2	1	1	72
1986	**Male**	19	1	3	0	1	24
	Female	21	5	1	1	1	29
	Total	40	6	4	1	2	53
1987	**Male**	12	1	0	0	3	16
	Female	17	5	3	0	0	25
	Total	29	6	3	0	3	41
1988	**Male**	23	2	0	0	0	25
	Female	31	2	1	0	1	35
	Total	54	4	1	0	1	60
1989	**Male**	15	5	3	0	0	23
	Female	31	2	2	0	2	37
	Total	46	7	5	0	2	60

Table 4-4-4-14: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For third age group (15 years and more), Glasgow.

		Numbers of later admissions					
		0	**1**	**2**	**3**	**More than 3**	**Total**
1984	**Male**	31	5	1	0	0	37
	Female	41	4	1	1	2	49
	Total	72	9	2	1	2	86
1985	**Male**	14	5	0	0	2	21
	Female	31	10	1	0	0	42
	Total	45	15	1	0	2	63
1986	**Male**	17	1	0	0	0	18
	Female	27	3	0	2	2	34
	Total	44	4	0	2	2	52
1987	**Male**	14	4	0	0	0	18
	Female	26	3	0	0	0	29
	Total	40	7	0	0	0	47
1988	**Male**	15	2	0	0	0	17
	Female	20	7	2	0	1	30
	Total	35	9	2	0	1	47
1989	**Male**	23	1	1	1	0	26
	Female	22	7	1	0	0	30
	Total	45	8	2	1	0	56

Table 4-4-4-15: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For third age group (15 years and more), Motherwell.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	2	1	1	0	0	4
	Female	1	0	0	0	0	1
	Total	3	1	1	0	0	5
1985	Male	7	1	0	0	0	8
	Female	7	1	0	0	0	8
	Total	14	2	0	0	0	16
1986	Male	6	0	0	1	0	7
	Female	4	1	1	0	0	6
	Total	10	1	1	1	0	13
1987	Male	5	0	0	0	0	5
	Female	4	0	0	0	0	4
	Total	9	0	0	0	0	9
1988	Male	7	0	0	0	0	7
	Female	6	1	0	0	0	7
	Total	13	1	0	0	0	14
1989	Male	8	1	0	0	0	9
	Female	7	1	1	0	0	9
	Total	15	2	1	0	0	18

Table 4-4-4-16: Numbers of patients (of first admission of type 4) with different number of later admissions in different sexes and cohorts of first admission. For third age group (15 years and more), Pooled* city.

		Numbers of later admissions					
		0	1	2	3	More than 3	Total
1984	Male	15	1	0	0	0	16
	Female	18	4	1	0	0	23
	Total	33	5	1	0	0	39
1985	Male	20	1	1	0	2	24
	Female	25	6	2	2	0	35
	Total	45	7	3	2	2	59
1986	Male	20	2	0	0	0	22
	Female	24	0	1	0	0	25
	Total	44	2	1	0	0	47
1987	Male	19	3	0	0	1	23
	Female	21	3	1	1	0	26
	Total	40	6	1	1	1	49
1988	Male	17	3	1	1	0	22
	Female	26	3	2	1	0	32
	Total	43	6	3	2	0	54
1989	Male	28	1	0	0	0	29
	Female	30	2	3	0	1	36
	Total	58	3	3	0	1	65

*pooled city includes Dundee, Kilmarnock and Paisley.

Table 4-4-4-17 shows the logistic model which is fitted to probability of "Having More Than Two Later Asthma Admissions" in a 3 year horizon after first asthma admission for the patients whose first asthma admissions were type 4. The scaled deviance of the model which includes only the constant term (this model is not shown here), was 177.58 with 171 degree of freedom. It implies the scaled deviance of the model which includes only the constant term is not significantly different from the scaled deviance of the saturated model. Note this model (the model which includes only the constant term) is considered an exactly similar binomial distribution for all counts (i.e. number of later asthma admissions) in all cells of contingency table. Even the scaled deviance of the model which includes only the constant term is not significantly different from the scaled deviance of the saturated model but entering the factor age group in the model changes the scaled deviance significantly. It means the factor age group is significantly related to the probability of "Having More Than Two Later Asthma Admissions". This is the model which is shown in table 4-4-4-17. Entering the other factors does not change the scaled deviance significantly i.e. the other factors (sex, year of first admission and city and 2 factors interaction terms) are not significantly related to probability of having more than two later asthma admissions of type 4 in a 3 year horizon after first asthma admission.

Table 4-4-4-17 implies that babies are more likely than children and adults to have more than two later asthma admissions after first asthma admission (in a 3 year horizon after first asthma admission). Children and Adults are equally at risk of having more than two later asthma admissions in a 3 year horizon after first asthma admission.

Table 4-4-4-17 : Logistic model for probability of "Having more than two later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 4.

Final model : C+α(Age)

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age	20.64	2	P<.0001, Sig.			
Sex				0.183	1	P=.6688, N.S.
Year				6.984	5	P=.2218, N.S.
City				3.394	4	P=.4942, N.S.
Age.Sex+Sex				0.433	3	P=.9333, N.S.
Age.Year+Year				14.84	15	P=.4630, N.S.
Age.City+City				8.486	12	P=.7160, N.S.
Sex.Year+ Sex+Year				9.714	11	P=.5563, N.S.
Sex.City+ Sex+City				5.685	9	P=.7710, N.S.
Year.City+ Year+City				29.00	29	P=.4651, N.S.

scaled deviance = 156.94 residual df = 169 from 172 observations.

	estimate	s.e.	parameter
1	-2.300	0.1638	1
2	-1.038	0.4440	FAGE_GRP(2)
3	-1.027	0.2269	FAGE_GRP(3)

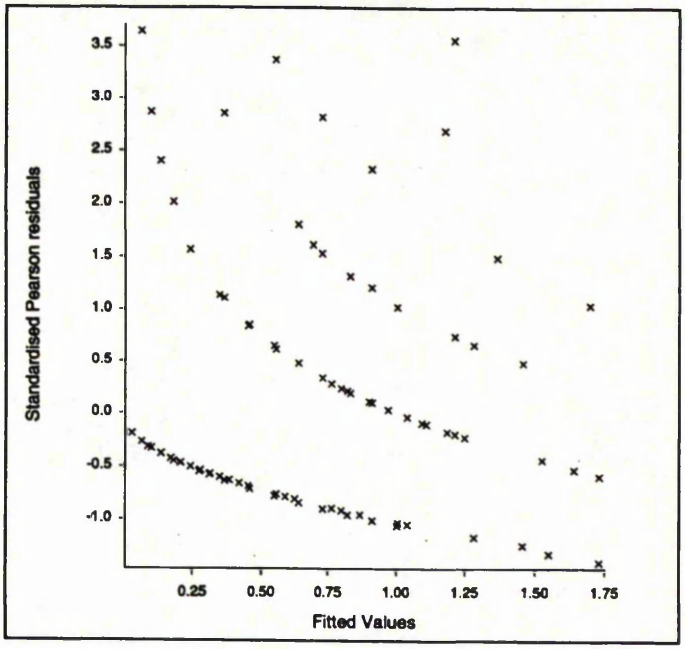
scale parameter 1.000

Plot 4-4-4-4 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-4-17.

[-1.600,-1.200) 3 SSS
[-1.200,-0.800) 21 SSSSSSSSSSSSSSSSSSSSS
[-0.800,-0.400) 52 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[-0.400, 0.000) 43 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.000, 0.400) 13 SSSSSSSSSSSSS
[0.400, 0.800) 11 SSSSSSSSSSS
[0.800, 1.200) 5 SSSSS
[1.200, 1.600) 5 SSSSS
[1.600, 2.000) 5 SSSSS
[2.000, 2.400) 4 SSSS
[2.400, 2.800) 6 SSSSSS
[2.800, 3.200) 3 SSS
[3.200, 3.600] 1 S

Mean = 0.001 S.D. = 1.021

Plot 4-4-4-5 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-4-17.



Plot 4-4-4-6 : Scatter plot of fitted values against actual values for model of table 4-4-4-17.

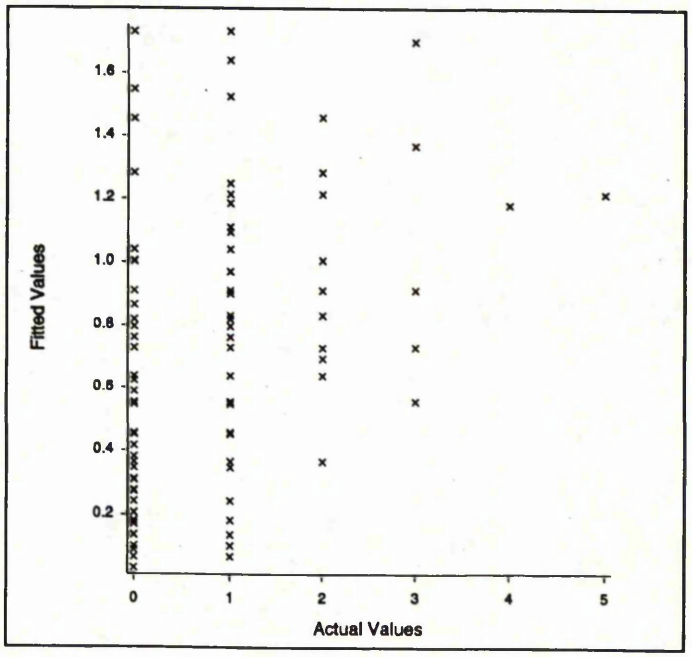


Table 4-4-4-18 shows the numbers of asthmatic patients (with first admissions of type 4) with 0, 1, 2, 3 and more than 3 later admissions in different age groups. Note that age was the only factor which was included in model of table 4-4-4-17.

Table 4-4-4-18: Numbers of patients (of first admission type 4) with different number of later admissions in different age groups.

	Numbers of later admissions					
	0	**1**	**2**	**3**	**More than 3**	**Total**
0-2 years	304	76	29	26	15	450
3-14 years	139	26	4	4	2	175
15 years and older	976	149	45	25	17	1212
Total	1419	251	78	55	34	1837

Table 4-4-4-19 shows the logistic model which is fitted to probability of "Having More Than Three Later asthma Admissions" in a 3 year horizon after first admission of type 4. The scaled deviance of the model which includes the constant term only, was 148.48 with 172 degree of freedom (this model is not shown here). Note the scaled deviance of this model is not significantly different from the scaled deviance of the saturated model. Table 4-4-4-19 indicates the factor age group is the only factor which is significantly related to probability of "Having More Than Three Later Asthma Admissions". The table suggests that babies are more at risk of having more than three later asthma admissions than children or adults. Children and adults are almost equally at risk of having more than three later asthma admissions in a 3 year horizon after first asthma admission.

Table 4-4-4-19 : Logistic model for probability of "Having more than three later asthma admissions" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 4.

Final model : C+α(Age)

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic	d.f.	Results
Age	13.88	2	P=.0010, Sig.			
Sex				0.000	1	P=1, N.S.
Year				4.412	5	P=.4917, N.S.
City				4.988	4	P=.2885, N.S.
Age.Sex+ Sex				0.969	3	P=.8088, N.S.
Age.Year+ Year				13.66	15	P=.5515, N.S.
Age.City+ City				14.67	12	P=.2600, N.S.
Sex.Year+ Sex+Year				10.95	11	P=.4475, N.S.
Sex.City+ Sex+City				12.87	9	P=.1686, N.S.
Year.City+ Year+City				25.11	29	P=.6725, N.S.

scaled deviance = 134.60 residual df = 169 from 172 observations.

	estimate	s.e.	parameter
1	-2.792	0.2020	1
2	-0.9629	0.5352	FAGE_GRP(2)
3	-1.069	0.2855	FAGE_GRP(3)

scale parameter 1.000

Plot 4-4-4-7 : Histogram of standardised Pearson Residuals for logistic model of table 4-4-4-19.

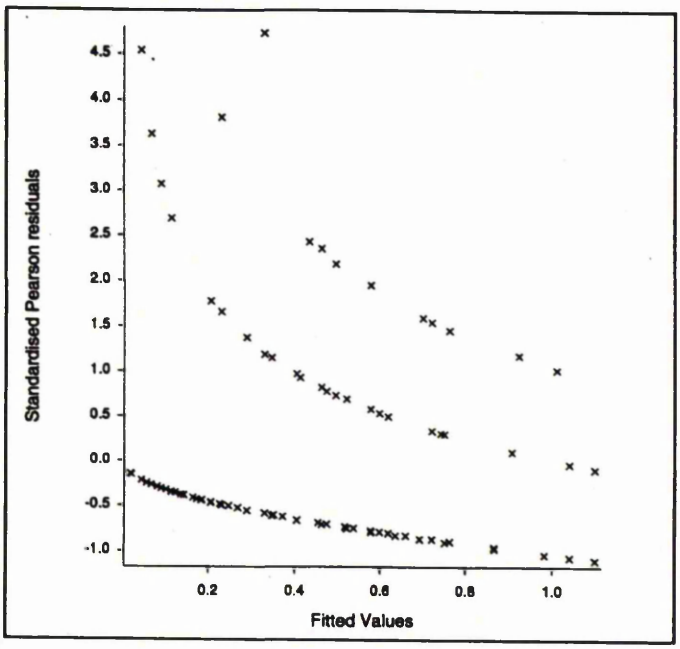
[-1.500,-1.000) 3 SS
[-1.000,-0.500) 44 SSSSSSSSSSSSSSSSSSSSS
[-0.500, 0.000) 85 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
[0.000, 0.500) 5 SSS
[0.500, 1.000) 11 SSSSSS
[1.000, 1.500) 7 SSSS
[1.500, 2.000) 7 SSSS
[2.000, 2.500) 3 SS
[2.500, 3.000) 1 S
[3.000, 3.500) 2 S
[3.500, 4.000) 2 S
[4.000, 4.500) 0
[4.500, 5.000] 2 S

Mean = 0.018 S.D. = 1.046

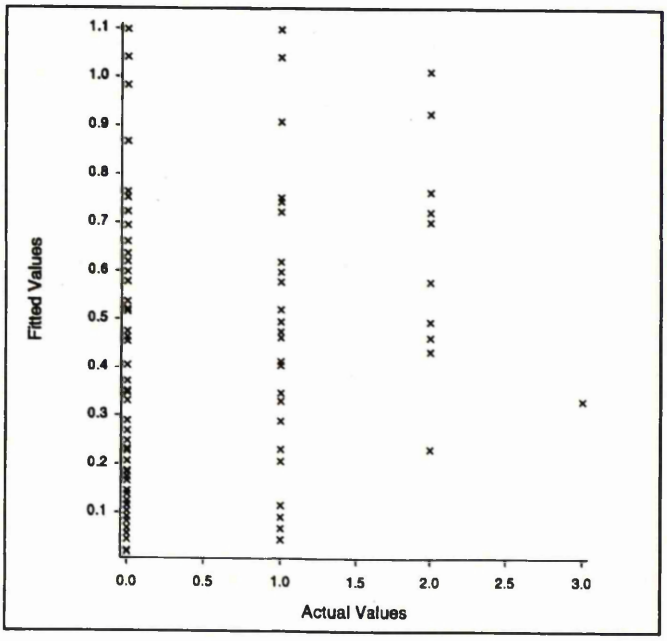
Since same factor is included in model 4-4-4-19 as in model 4-4-4-17 therefore we refer reader to table 4-4-4-18 to see the descriptive data of later admissions in different levels of included factor.

Note the effect of age group on having later asthma admissions for those patients whose first asthma admissions are type 4 in all tables 4-4-4-1, 4-4-4-17 and 4-4-4-19 are much smaller than its effect on later asthma admissions of those patients whose first asthma admissions are type 1 or 2. We remind the reader that age group had no effect on number of later asthma admissions of those patients whose first asthma admissions were type 3 (second diagnosis as asthma and non emergency admitted).

Plot 4-4-4-8 : Scatter plot of standardised Pearson residuals against fitted values for model of table 4-4-4-19.



Plot 4-4-4-9 : Scatter plot of fitted values against actual values for model of table 4-4-4-19.



4-5 : Tables of Probabilities for Having Different Number of Later Admissions :

In this section we show some tables of probabilities due to later asthma admissions of asthmatic patients. These tables are prepared for different types of first asthma admission. For each group of asthmatic patients with similar type of first asthma admission 3 tables are produced which are due to probability of "Not Returning to Hospital", "Having More Than Two Later Asthma Admissions" and "Having More Than Three Later Asthma Admissions". These probabilities are shown in different combination of 2 factors age group and sex. At the end we introduce 3 more tables which show the probability of 3 above mentioned events for each type of first asthma admission without considering age group or sex of patients.

Tables 4-5-1 to 4-5-3 show the probability of, respectively, "Not Returning to Hospital", "Having More Than Two Later Asthma Admissions" and "Having More Than Three Later Asthma Admissions" in different combination of 2 factors age group and sex for those patients whose type of first asthma admissions are type 1. Recall that for patients with first asthma admission of type 1 (non emergency admission and first diagnosis as asthma), the probability of "Not Returning to Hospital" depends only to factor "sex" (refer to table 4-4-1-1) while the probabilities of "Having More Than Two Later Asthma Admissions" or "Having More Than Three Later Asthma Admissions" depends to the interaction between two factors "sex" and "year of first asthma admission (refer to tables 4-4-1-3 and 4-4-1-5). Note it is the reason that two factors "sex" and "year of first asthma admission" are included

in these two recent models. It implies the tables of probabilities which are prepared for first asthma admission of type 2, and have been prepared in different combinations of "sex" and "age group", can not be used for reading the probabilities of "Having more than two later asthma admissions" or "Having more than three later asthma admissions". We prepared these tables (tables of probabilities) for different combinations of "age group" and "sex" because in most models (as we noticed in sections 4-2 to 4-4) two factors "age group" and "sex" and their interaction were the only factors which were significantly related to the mentioned probabilities. Hence if any of these probabilities is only related to one of these factors (one of factors "age group" or "sex") or to none of these factors, then the correct probability is possible to be read from the related column or row or the total cell. Note that, as we discovered in sections 4-4-2 to 4-4-4, for patients with some other types of first asthma admissions, the two factors age group and sex and sometimes the interaction between these two factors are significantly related to these probabilities, therefore we decided to prepare some tables with a common structure for all types of first asthma admissions. Anyway note that one who is, for example interested in only a particular probability (for example probability of "Not Returning to Hospital") in different sexes, could see this probability by looking at total rows which gives the total probability for different sexes. In addition to this, we have given the 95% confidence intervals for each point estimate, so that the reader is able to compare whether the two probabilities are or are not significantly different.

Tables 4-5-13 to 4-5-15 shows different probabilities for 4 different types of first asthma admission. In each of these tables the probability of "Not Returning to Hospital", or the probability of "Having More Than Two Later

Asthma Admissions" or the probability of "Having More Than Three Later Asthma Admissions", for a particular type of first admission, are shown.

These tables indicate that first admission of type 2 and 3 are always opposite to each other. For instance, table 4-5-13 indicates that the smallest probability of "Not Returning to Hospital" is due to those patients whose first asthma admissions are type 2 while the largest probability of "Not Returning to Hospital" is due to the patients with first asthma admission of type 3. Tables 4-5-14 and 4-5-15 show that the largest probability of either "Having More Than Two Later Asthma Admissions" or "Having More Than Three Later Asthma Admissions" is due to patients with first asthma admissions of type 2 while the smallest of these probabilities belong to those whose first asthma admissions are type 3.

Table 4-5-1 : Probability of "Not returning to hospital" in a 3 years horizon after first admission for first admissions of type 1 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.78 94 (0.70 , 0.86)	0.87 24 (0.74, 1)	0.75 331 (0.70 , 0.80)	0.72 449
Female	0.57 33 (0.40 , 0.74)	0.76 41 (0.63 , 0.89)	0.70 420 (0.66 , 0.74)	0.70 494
Total	0.72 127	0.80 65	0.72 751	0.73 943

Table 4-5-2 : Probability of "Having more than two later admissions" in a 3 years horizon after first admission for first admissions of type 1 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.04 94 (0.0 , 0.08)	0.0 24	0.04 331 (0.02 , 0.06)	0.03 449
Female	0.15 33 (0.03 , 0.27)	0.03 41 (0.0 , 0.08)	0.09 420 (0.06 , 0.12)	0.07 494
Total	0.07 127	0.01 65	0.05 751	0.05 943

Table 4-5-3 : Probability of "Having more than three later admissions" in a 3 years horizon after first admission for first admissions of type 1 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.02 94 (0.0 , 0.05)	0.0 24	0.03 331 (0.01 , 0.05)	0.02 449
Female	0.06 33 (0.0 , 0.14)	0.02 41 (0.0 , 0.06)	0.04 420 (0.02 , 0.06)	0.04 494
Total	0.03 127	0.015 65	0.03 751	0.03 943

Table 4-5-4 : Probability of "Not returning to hospital" in a 3 years horizon after first admission for first admissions of type 2 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.61 4855 (0.60 , 0.62)	0.81 887 (0.78, 0.84)	0.74 2305 (0.72 , 0.76)	0.67 8047
Female	0.59 2437 (0.57 , 0.61)	0.71 1221 (0.68 , 0.74)	0.72 3547 (0.71 , 0.73)	0.67 7205
Total	0.61 7292	0.75 2108	0.73 5852	0.67 15252

Table 4-5-5 : Probability of "Having more than two later admissions" in a 3 years horizon after first admission for first admissions of type 2 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.12 4855 (0.11 , 0.13)	0.04 887 (0.03, 0.05)	0.05 2305 (0.04 , 0.06)	0.09 8047
Female	0.14 2437 (0.13 , 0.15)	0.07 1221 (0.06 , 0.08)	0.05 3547 (0.04 , 0.06)	0.08 7205
Total	0.13 7292	0.06 2108	0.05 5852	0.09 15252

Table 4-5-6 : Probability of "Having more than three later admissions" in a 3 years horizon after first admission for first admissions of type 2 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.08 4855 (0.07 , 0.09)	0.02 887 (0.01, 0.03)	0.03 2305 (0.2 , 0.04)	0.06 8047
Female	0.09 2437 (0.08 , 0.10)	0.04 1221 (0.03 , 0.05)	0.03 3547 (0.02 , 0.04)	0.05 7205
Total	0.08 7292	0.03 2108	0.03 5852	0.06 15252

Table 4-5-7 : Probability of "Not returning to hospital" in a 3 years horizon after first admission for first admissions of type 3 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.81 99 (0.73 , 0.89)	0.90 41 (0.81, 0.99)	0.84 160 (0.78 , 0.90)	0.84 300
Female	0.87 48 (0.77 , 0.97)	0.94 37 (0.86 , 1)	0.84 289 (0.80 , 0.88)	0.86 374
Total	0.83 147	0.92 78	0.84 449	0.85 674

Table 4-5-8 : Probability of "Having more than two later admissions" in a 3 years horizon after first admission for first admissions of type 3 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.02 99 (0.0 , 0.05)	0.0 41	0.04 160 (0.01 , 0.07)	0.03 300
Female	0.0 48	0.03 37 (0.0 , 0.08)	0.01 289 (0.0 , 0.02)	0.01 374
Total	0.01 147	0.01 78	0.02 449	0.016 674

Table 4-5-9 : Probability of "Having more than three later admissions" in a 3 years horizon after first admission for first admissions of type 3 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.01 99 (0.0 , 0.03)	0.0 41	0.03 160 (0.0 , 0.06)	0.02 300
Female	0.0 48	0.03 37 (0.0 , 0.08)	0.003 289 (0.0 , 0.009)	0.005 374
Total	0.007 147	0.01 78	0.01 449	0.01 674

Table 4-5-10 : Probability of "Not returning to hospital" in a 3 years horizon after first admission for first admissions of type 4 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.68 315 (0.63 , 0.73)	0.83 97 (0.76, 0.90)	0.83 515 (0.80 , 0.86)	0.78 927
Female	0.65 135 (0.57 , 0.73)	0.74 78 (0.64 , 0.84)	0.79 697 (0.76 , 0.82)	0.76 910
Total	0.67 450	0.79 175	0.80 1212	0.77 1837

Table 4-5-11 : Probability of "Having more than two later admissions" in a 3 years horizon after first admission for first admissions of type 4 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.09 315 (0.06 , 0.12)	0.03 97 (0.0 , 0.06)	0.03 515 (0.02 , 0.04)	0.05 927
Female	0.09 135 (0.04 , 0.14)	0.04 78 (0.0 , 0.08)	0.04 697 (0.03 , 0.05)	0.04 910
Total	0.09 450	0.03 175	0.03 1212	0.05 1837

Table 4-5-12 : Probability of "Having more than three later admissions" in a 3 years horizon after first admission for first admissions of type 4 in different combinations of age group and sex.

	Baby (0-2 years) Prob. no. of patients Con. Interval	**Child (3-14 years)** Prob. no. of patients Con. Interval	**Adult (More than 14)** Prob. no. of patients Con. Interval	**Total** Prob. no. of patients
Male	0.05 315 (0.03 , 0.07)	0.03 97 (0.0 , 0.06)	0.02 515 (0.01 , 0.03)	0.03 927
Female	0.07 135 (0.03 , 0.11)	0.01 78 (0.0 , 0.03)	0.02 697 (0.01 , 0.03)	0.03 910
Total	0.06 450	0.02 175	0.02 1212	0.03 1837

Table 4-5-13 : Probability of "Not returning to hospital" in a 3 years horizon after first admission in different types of first admission.

Type of first admissions	**Probability, No. of patients, Conf. Interval**
Type 1	0.73 943 (0.70 , 0.76)
Type 2	0.67 15252 (0.66 , 0.68)
Type 3	0.85 674 (0.82 , 0.88)
Type 4	0.77 1837 (0.75 , 0.79)

Table 4-5-14 : Probability of "Having more than two later admissions" in a 3 years horizon after first admission in different types of first admission.

Type of first admissions	Probability, No. of patients, Conf. Interval
Type 1	0.05 943 (0.04 , 0.06)
Type 2	0.09 15252 (0.085 , 0.095)
Type 3	0.02 674 (0.01 , 0.03)
Type 4	0.05 1837 (0.04 , 0.06)

Table 4-5-15 : Probability of "Having more than three later admissions" in a 3 years horizon after first admission in different types of first admission.

Type of first admissions	Probability, No. of patients, Conf. Interval
Type 1	0.03 943 (0.02 , 0.04)
Type 2	0.06 15252 (0.056 , 0.064)
Type 3	0.01 674 (0.002 , 0.018)
Type 4	0.03 1837 (0.02 , 0.04)

4-6 : Use of Cumulative Conditional Logistic Model in Fitting Common Coefficients to Different Cut Points of Conditional Probability Distribution Function of Later Asthma Admissions (Type 2):

So far in section 4-4 we fitted several logistic models to different cut points of probability distribution function of later asthma admissions corresponding to first admission of types 1 to 4. The cut points which were considered there were "not returning to hospital", "having more than 2 later admissions" and "having more than 3 later admissions". 3 of fitted models were due to those patients whose first admissions were type 2. In these 3 fitted models, even the same factors and interaction terms were included in the models[1], but the coefficients of the fitted models were different. In this section we use a new approach and will fit a common model to different cut points of probability distribution function of those patients whose first asthma admissions are type 2. We do not consider asthmatic patients with other types of first admission.

To carry out the idea, in section 4-6-2 we first fit 3 logistic models to Probabilities of "having more than zero later admission" (i.e. returning to hospital), "having more than 2 later admissions given that patient has already returned to hospital" and "having more than 3 later admissions given that patient has already had more than 2 later admissions". In section 4-6-3 we

[1] In all these 3 models age, sex and the interaction between age and sex were included in the model.

illustrate the use of cumulative conditional logistic model to fit a common model to all these 3 cut points. In this model common coefficients will be estimated for these cut points. Then in section 4-6-4 we compare the results of sections 4-6-2 and 4-6-3. But first in section 4-6-1 we introduce the cumulative conditional logistic model and will derive its likelihood and discuss how this model works.

4-6-1 : Cumulative Conditional Logistic Model

Suppose,

X= Number of later asthma admissions for a (type 2) patient with a particular combination of factors, and

n= Total number of asthmatic patients in the cell.

Now we consider three probabilities;

$$P(X>0) = q_0$$

$$P(X>2 \mid X>0) = q_2$$

$$P(X>3 \mid X>2) = q_3$$

Note that q_0 , q_2 and q_3 can be modelled separately using logistic model. In this case the coefficients of factors in different models could be different and even different factors could be relevant to q_0 , q_2 and q_3 . Here we are interested to fit a single model to all probabilities q_0 , q_2 and q_3 to have common coefficients for all these probabilities. Suppose we want to fit the following single logistic model,

$$q_0 = \exp[\theta_0+\alpha_i+\beta_j+(\alpha\beta)_{ij}] \,/\, \{1+ \exp[\theta_0+\alpha_i+\beta_j+(\alpha\beta)_{ij}]\}$$

$$q_2 = \exp[\theta_2+\alpha_i+\beta_j+(\alpha\beta)_{ij}] \,/\, \{1+ \exp[\theta_2+\alpha_i+\beta_j+(\alpha\beta)_{ij}]\}$$

$$q_3 = \exp[\theta_3+\alpha_i+\beta_j+(\alpha\beta)_{ij}] \,/\, \{1+ \exp[\theta_3+\alpha_i+\beta_j+(\alpha\beta)_{ij}]\}$$

For the moment we consider only two factors and the interaction term. The reason is that in section 4-4-2 we discovered that number of later asthma admissions of those patients whose first admission are type 2, is only related to two factors age and sex and the interaction between age and sex. Note that in

above equations the constant term is the only coefficient which varies from one model to another. To write down the likelihood of the above model, suppose for the n male babies we have $n = n_a + n_b + n_c + n_d$, where

n_a = Number of male babies with zero later admissions,

n_b = Number of male babies with 1 and 2 later admissions,

n_c = Number of male babies with 3 later admissions, and

n_d = Number of male babies with more than 3 later admissions.

That is a multinomial sample with cell probabilities;

$$P(X = 0) = 1 - q_0$$

$$P(X = 1,2) = q_0 (1 - q_2)$$

$$P(X = 3) = q_0 q_2 (1 - q_3)$$

$$P(X > 3) = q_0 q_2 q_3$$

Note,

$$P(X = 0) + P(X = 1,2) + P(X = 3) + P(X > 3) = [1 - q_0] + [q_0 (1 - q_2)] + [q_0 q_2 (1 - q_3)] + [q_0 q_2 q_3] = 1.$$

So the contribution of male babies to likelihood is,

$$[1 - q_0]^{n_a} [q_0 (1 - q_2)]^{n_b} [q_0 q_2 (1 - q_3)]^{n_c} [q_0 q_2 q_3]^{n_d}$$

$$= [1 - q_0]^{n_a} q_0^{n_b + n_c + n_d} \times [1 - q_2]^{n_b} q_2^{n_c + n_d} \times [1 - q_3]^{n_c} q_3^{n_d}$$

Hence that the likelihood is the result of multiplication of three separate binomials' likelihood corresponding to probabilities q_0 , q_2 and q_3 . Therefore if we define a dummy variable to indicate to which probability the number of successes belongs to, then we can fit a single model to all three probabilities q_0 , q_2 and q_3 . In this case, if the 3 age groups which are used in chapter 4 are

coded as 1, 2, and 3 and sex is coded as 1 and 2 then the data for male babies should be arranged as,

Total	No. of Success	Dummy	Sex	Age
$n_a+n_b+n_c+n_d$	$n_b+n_c+n_d$	1	1	1
$n_b+n_c+n_d$	n_c+n_d	2	1	1
n_c+n_d	n_d	3	1	1

Note that,

$n_a+n_b+n_c+n_d$ = Total number of male babies (i.e. total No. of male babies first admission),

$n_b+n_c+n_d$ = No. of male babies patients who have more than zero later admissions,

n_c+n_d = No. of male babies patients who have more than 2 later admissions,

n_d = No. of male babies patients who have more than 3 later admissions.

We can read in data for other age groups and sexes similarly and then fit the model which should include the dummy variable as a main effect (θ_0, θ_2, θ_3) as well as the main effects and interaction of age and sex, if significant.

In 4-6-3 the remaining factors city and year were also candidates for inclusion in the models, in addition to age and sex.

Note that the "conditional" approach just described avoids the need for specialised software associated with "ordinal logistic regression". Standard software for logistic regression is sufficient, e.g. GLIM.

4-6-2 : Fitting Separate Logistic models to Different Cut Points:

In this section we fit 3 separate logistic models to 3 cut points of probability distribution of later asthma admissions of those patients whose first admissions are type 2.

The first cut point is the event of "returning to hospital i.e. having more than zero later asthma admission". Table 4-6-2-1 shows the final logistic model which is fitted to probability of "having more than zero later admissions". This model is derived from model of table 4-4-2-1 in section 4-4-2. Recall that in section 4-4-2 we fitted a logistic model to probability of "having zero later admissions". Note that since,

$$\text{Log}\{P(X>0)/[1-P(X>0)]\} = \text{Log}\{[1-P(X=0)]/[1-[1-P(X=0)]]\}$$
$$= \text{Log}\{[1-P(X=0)]/P(X=0)]\}$$
$$= -\text{Log}\{P(X=0)/[1-P(X=0)]\}$$

we can obtain the fitted logistic model to P(X>0) just by simply multiplying the coefficients of model of table 4-4-2-1 in a minus sign. In section 4-4-2 we showed that this model is fitted fairly well.

Table 4-6-2-1: Fitted logistic model to probability of "having more than zero later admissions" in a 3 year horizon after first admission. For patients whose first admissions are type 2.

scaled deviance = 199.1 residual df = 174 from 180 observations

	estimate	s.e.	parameter
1	-0.4520	0.02944	1
2	-1.002	0.09053	FAGE_GRP(2)
3	-0.5991	0.05592	FAGE_GRP(3)
4	0.09117	0.05062	SEX(2)
5	0.4590	0.1178	FAGE_GRP(2).SEX(2)
6	-0.01001	0.07897	FAGE_GRP(3).SEX(2)

scale parameter 1.000

Table 4-6-2-2 shows the logistic model which is fitted to conditional probability of "having more than 2 later admissions given that patient has already more than zero later admission". The scaled deviance of the model is 210.07 with 176 degree of freedom. It indicates that age alone gives a good fit. This table indicates that this conditional probability depends only on factor age group. Table 4-6-2-2 shows that among those asthmatic patients (with first

Table 4-6-2-2 : Logistic model for probability of "having more than 2 later admissions given that patient has already more than zero later admission" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 2.

Final model : C+α(Age).

Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age	90.2	2	P<.0001, Sig.			
Sex				0.54	1	P=.4624, NS
Year				4.976	5	P=.4831, NS
City				5.307	4	P=.2572. NS.
Age*Sex+Sex				1.752	3	P=.6254, NS
Age*Year+Year				12.6	15	P=.6332, NS
Age*City+City				17.61	12	P=.8546, NS
Sex*Year+ sex+Year				6.272	11	P=.8546, NS
Sex*City +Sex+City				9.614	9	P=.3826, NS
Year*City +Year+City				39.27	29	P=.0966, NS

```
scaled deviance=210.07 residual df =176 from 179 observations
          estimate        s.e.     parameter
     1     -0.7229      0.03967       1
     2     -0.4919      0.1116      FAGE_GRP(2)
     3     -0.6610      0.07443     FAGE_GRP(3)
scale parameter 1.000
```

admissions of type 2) who have returned to hospital at least once, patients in both age group 2 (3-14 years old) and 3 (15 years or more) are less likely than babies (0-2 years old) to have more than 2 later admissions. Plots 4-6-2-1 and 4-6-2-2 are prepared to investigate the goodness of fit of the model of table 4-6-2-2. Even the plot 4-6-2-1 shows slight decrease in residuals' variance, plot 4-6-2-2 indicates the model is fitted fairly well.

Table 4-6-2-3 shows the fitted logistic model to probability of "having more than 3 later admissions given that asthmatic patient has already more than 2 later admissions". The scaled deviance of the model is 209.33 with 160 degree of freedom (significantly large). This model indicates that the city is the

Table 4-6-2-3 : Logistic model for probability of "having more than 3 later admissions given that patient has already more than 2 later admission" in a 3 year horizon after first asthma admission. For asthmatic patients whose first asthma admissions are type 2.

Final model : C+α(City).

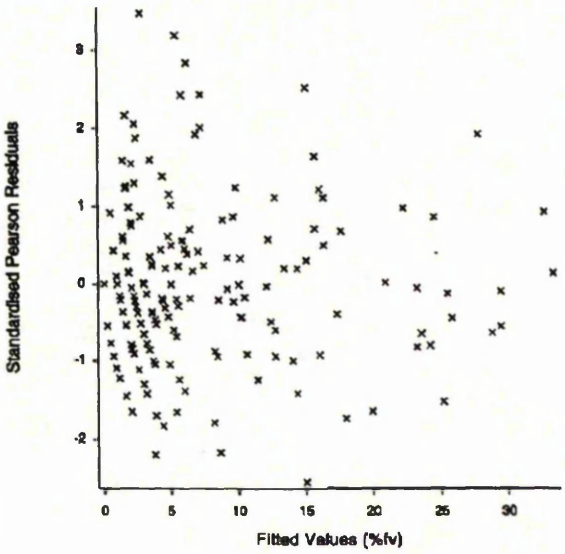
Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
City	10.12	4	P=.0385, NS			
Age				4.486	2	P=.1061, NS
Sex				1.496	1	P=.2213, NS
Year				2.121	5	P=.8322, NS
City*Age+Age				10.3	10	P=.4146, NS
City*Sex+Sex				3.5	5	P=.6234, NS
City*Year +Year				17.34	25	P=.8691, NS
Age*Sex +Age+Sex				8.481	5	P=.1316, NS
Age*year +Age+Year				14.32	17	P=.6443, NS
Sex*Year +Sex+Year				12.85	11	P=.3032, NS

```
scaled deviance =  209.33 df =160 from 165 observations
            estimate        s.e.      parameter
     1       0.6931       0.1622       1
     2      -0.3072       0.1962       CITY(2)
     3      0.05318       0.1967       CITY(3)
     4      -0.2231       0.2363       CITY(4)
     5      -0.3673       0.1948       CITY(5)
scale parameter 1.000
```

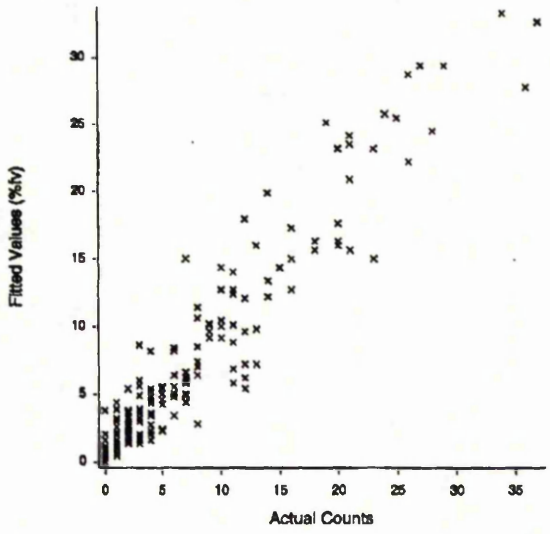
only factor which is related to probability of having more than 3 later admissions given that

patient has already more than 2 later admissions. Plots 4-6-2-3 and 4-6-2-4 are prepared to investigate the goodness fit of the model of table 4-6-2-3. Both plots indicate that although the scaled deviance was significantly large, the model is fairly well fitted.

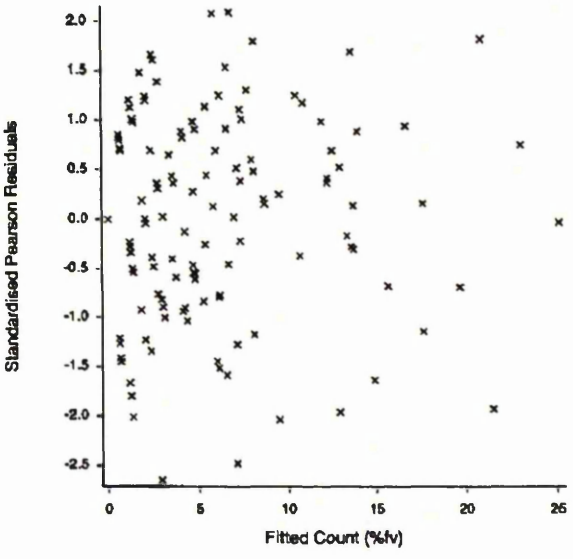
Plot 4-6-2-1: Scatter plot of standardised Pearson residuals against the fitted values for model of table 4-6-2-2.



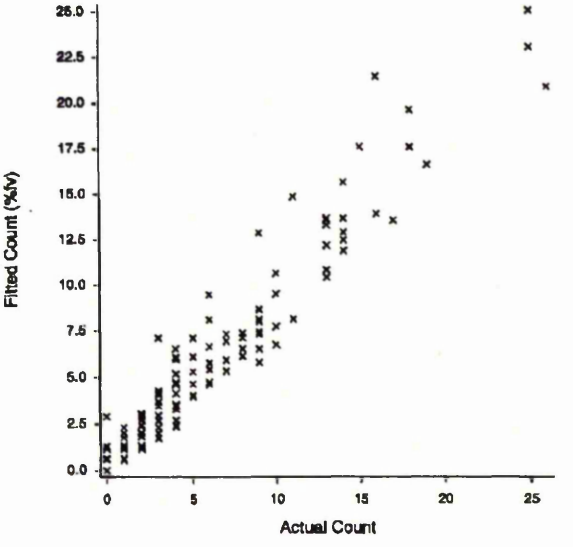
Plot 4-6-2-2: Scatter plot of fitted values against the actual values for model of table 4-6-2-2.



Plot 4-6-2-3: Scatter plot of standardised Pearson residuals against the fitted values for model of table 4-6-2-3.



Plot 4-6-2-4: Scatter plot of fitted values against the actual values for model of table 4-6-2-3.



4-6-3 : Fitting Conditional Logistic Model with Common Coefficients to Different Cut Points of Conditional Probability Distribution Function of Later admissions:

In section 4-6-1 we explained how the data should be arranged to fit a conditional logistic model with common coefficients to different cut points. In this section we fit a single cumulative conditional logistic model to all probabilities P(X>0), P(X>2|X>0) and P(X>3|X>2), where X=No. of later admissions. Recall that in section 4-6-2 we fitted separate logistic models to each of these probabilities. Later in section 4-6-4 we compare the results.

Table 4-6-3-1 shows the conditional logistic model which is fitted to all 3 cut points P(X>0), P(X>2|X>0) and P(X>3|X>2) simultaneously. The scaled deviance of the model is 631.67 with 516 degree of freedom. Note that the scaled deviance is significantly large. Plots 4-6-3-1 and 4-6-3-2 are prepared to investigate the goodness of fit of the model of table 4-6-3-1. Both these plots indicate that the model of table 4-6-3-1 is fairly well fitted. The fitted model indicates that 3 (conditional) probabilities are significantly related to two factors age and sex and also to interaction between these two factors. It shows that asthmatic patients who, at time of first admission, are in age groups 2 (3-14 years old) or 3 (15 years and older) are less likely to have later admissions. The fitted model suggests also that female patients are more likely than male patients to have later admissions. Three separate models which can be derived from the above fitted model differ only in constant term.

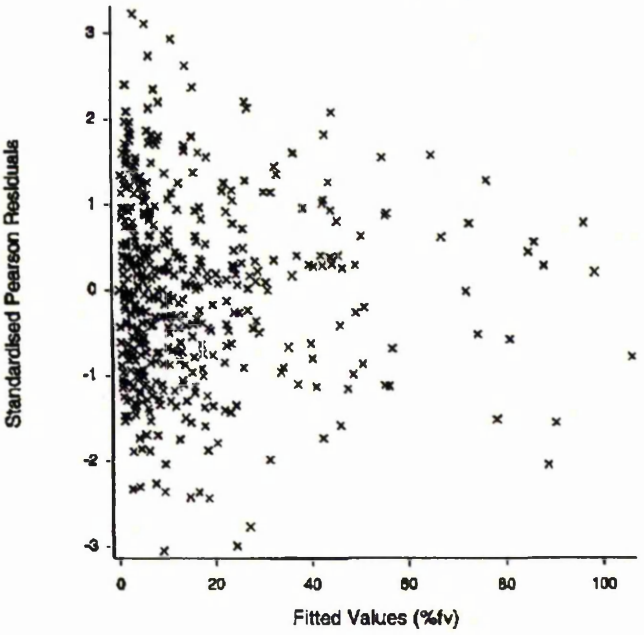
Table 4-6-3-1 : Logistic model fitted simultaneously to three probabilities P(X>0), P(X>2|X>0) and P(X>3|X>2). For asthmatic patients whose first asthma admissions are type 2.

Final model : C+θ(Dummy)+α(Age)+β(Sex)+γ(Age.Sex).

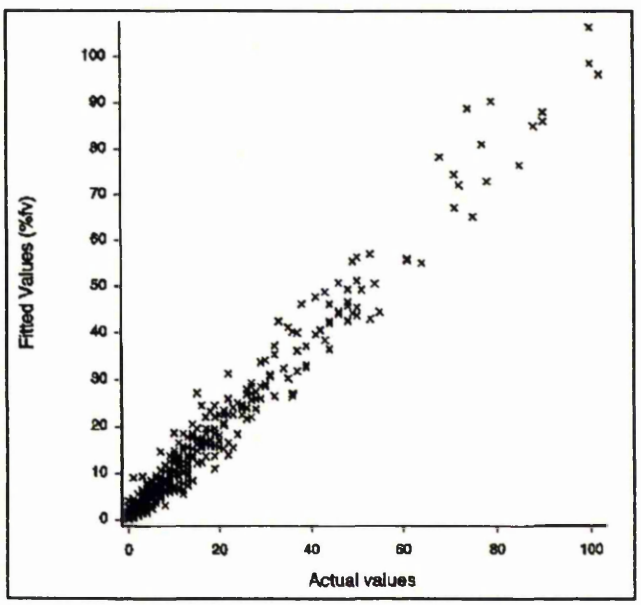
Variable to Enter or Remove	Removal			Inclusion		
	Test Statistic ($\chi 2$)	d.f.	Result	Test Statistic ($\chi 2$)	d.f.	Results
Age*Sex	19.87	2	P<.0001, Sig			
Year				5.446	5	P=.3639, NS
City				4.389	4	P=.3569, NS
Age*Year+Year				17.2	10	P=.0700, NS
Sex*Year+Year				2.744	5	P=.7394, NS
Age*City+City				6.935	8	P=.5437, NS
Sex*City+City				2.873	4	P=.5793, NS
Year*City+ Year+City				22.94	29	P=.7793, NS

```
scaled deviance =  631.67 residual df = 516 from 524 observations

          estimate        s.e.      parameter
     1      -0.4583     0.02648      1
     2      -0.3080     0.03657      DUMMY(2)
     3        1.129     0.05896      DUMMY(3)
     4      -0.9272     0.08007      FAGE_GRP(2)
     5      -0.5934     0.04854      FAGE_GRP(3)
     6      0.08554     0.04147      SEX(2)
     7       0.4332      0.1023      FAGE_GRP(2).SEX(2)
     8   -0.009944     0.06756      FAGE_GRP(3).SEX(2)
scale parameter 1.000
```

Plot 4-6-3-1: Scatter plot of standardised Pearson residuals against the fitted values for model of table 4-6-3-1.



Plot 4-6-3-2: Scatter plot of fitted values against the actual values for model of table 4-6-3-1.



4-6-4 : Comparing Results of Sections 4-6-2 and 4-6-3:

In section 4-6-2 and 4-6-3 we considered two approaches. In first approach we fitted separate logistic models to probabilities P(X>0), P(X>2|X>0) and P(X>3|X>2). In second approach we fitted a single logistic model to all these probabilities simultaneously. Here we compare the results and try to investigate whether the second approach was applicable or not.

First logistic model fitted to P(X>0) showed that this probability is related to two factors age and sex and their interaction. Second logistic model fitted to P(X>2|X>0) indicated that this probability is only relevant to factor age. Third logistic model showed that the P(X>2|X>0) is not related to any of factors age or sex but depends on factor city. Note that different factors are included in these three probabilities.

In next approach we fitted a single logistic model to all three probabilities simultaneously. This model showed that these three probabilities are related to two factors age and sex and their interaction. Note that the coefficients of age, sex and the interaction terms in model of table 4-6-2-1 (the model fitted to P(X>0))is fairly similar to same coefficients in model of table 4-6-3-1. It is difficult to compare the models of tables 4-6-3-2 and 4-6-3-3 with model of table 4-6-3-1. The reason is that these models include different factors.

It seems desirable to check whether the model of table 4-6-3-1 (we call it model M) should be generalised, to allow age and sex effects to depend on which of q_0, q_2, q_3 being considered. To do this, the following fits were carried out, using the theory of 4-6-1,

(1) M + Dummy * Age

(2) M + Dummy*Sex

(3) M + Dummy*Age + Dummy*Sex + Dummy*Age*Sex

A summary of results is as follows.

(1) Scaled deviance = 620.39, (df=512)

change = 11.28, (df = 4)

Formally significant (P=.024), i.e. different coefficients of age for q_0, q_2, q_3 . Possibly the differences from M (model of table 4-6-3-1) are not important.

(2) Scaled deviance = 627.65 (df=514)

change = 4.021 (df=2)

Not significant (P=.134), i.e. coefficients of sex same for q_0, q_2, q_3

(3) Scaled deviance = 617.48 (df=506)

change = 14.19 (df=10)

Not significant (P=.165), coefficients of interaction terms same for q_0, q_2, q_3.

It seems reasonable to adopt model M (table 4-6-3-1) for practical purposes.

4-7 : Summary :

In this chapter we modelled the later admissions of asthmatic patients in a 3 year horizon after first admission.

The Weighted Regression was used to investigate the relation between later asthma admissions, in a 3 year horizon after first admission, and a number of factors. The Logistic model also was used to model, at certain points, the probability function of number of returns to hospital. Fitted models to the mean of later admissions of patients whose first admissions were the most common type (i.e. first diagnosed, emergency admissions, called type 2) indicated that babies return to hospital more frequently than children and adults, and adults return more frequently than children. Among babies, the age group is the only factor which is related to mean of later asthma admissions i.e. mean of later asthma admissions of babies is not even related to factor "sex". For two other age groups (children and adults), the effect of age group is different for male and female. "Year of first admission" is also relevant. Girls and women return to hospital more frequently than males.

Probability tables of having 0 (i.e. not returning to hospital), more than 2 and more than three later admissions, are shown in chapter 4 as well. These tables confirm the importance of age and sex. The probability of "Not returning to hospital" for patients with first admission of types 1, 2, 3 and 4 are respectively, 0.73, 0.67, 0.85 and 0.77.

In section 4-6 we fitted separate logistic models to $P(X>0)$, $P(X>2|X>0)$ and $P(X>3|X>2)$. Then we used the cumulative conditional logistic regression and fitted a single model to all these 3 probabilities. In 4-6-4 we compared the

results and concluded that the single model, indicating age and sex effects, was satisfactory.

Chapter 5

Using Cox Regression to Model Different Times free of Admission

In this chapter we intend to use the Cox Proportional hazards model, which briefly called Cox Regression, to model different times free of admission. The main objectives of this chapter are to investigate the validation of results of chapter 4 as well as to investigate the relation between times free of admission and some covariates which could not to be investigated in the previous chapter. As an example of these types of covariates, the effect of previous time free of admission, or previous length of stay in hospital, on the current time free of admission can be mentioned.

The precise definition of time free of admission is defined in Appendix 1. Note that different times free of admission can be defined, i.e. first, second, third,... times free of admission. As it is defined in Appendix 1, each time free of admission is the time interval between the date of any admission and next immediate admission. Times free of admission are censored if the next admission has still not occurred.

In this chapter we consider only the first, second and third time free of admission. The reason simply is that we are not able to consider all times free of admission. We also restrict ourselves to fit survival models only to those

patients whose first asthma admission has been labelled as type 2. We remind the reader that 4 types of first asthma admissions exist and in previous chapters we focused on each of these types separately. Recall that the admissions of type 2 are those admissions which have been labelled as emergency admissions and correspond to those patients for whom asthma is their first reason of hospitalisation. There are several reasons for this choice. First, the admissions of type 2 are the most common type of admission. Second, since we are going to fit Cox models up to third time free of admission, it is not clear whether we have enough data to do so for other types of admissions.

In this chapter, we first (in section 5-1) introduce a brief summary about survival models as well as Cox Proportional Hazard model. Since we intend to use "Log Minus Log Plot", to investigate the validation of the proportional hazard assumption, and to use Cox-Snell residuals to carry out an overall test for goodness of fit of the models, these two procedures will be explained in detail. In sections 5-2 to 5-4, the Cox models which are fitted to, respectively, first, second and third times free of admission are shown. A summary of chapter 5 is given in section 5-5. The SPSS statistical software (Ver.s 6.1, 6.2 and 6.3) for windows, is used in this chapter to fit all the models.

5-1 : Introduction to Survival Models :

In this section we introduce survival models and some of their key aspects. Then we introduce the various types of these models including hazards based models and the Cox Proportional Hazards model in particular. Finally we will give some reasons for using the Cox Proportional Hazards model in analysing our data.

5-1-1: Survival Models:

Survival models are those types of models which are used for analysing failure times. These models have as the response variable the length of time to 'end events'. Such events may be, for example, between birth and death, between marriage and divorce, between start of treatment and death or between start of treatment and 'cure' of a particular disease. The length of time between such events, which is actually the response variable, is called 'survival time', 'life time' or 'failure time'. (Cox D.R. 1984)

Note that to determine the failure time precisely, there are requirements:

a) A time origin must be unambiguously defined. It is the time at which the subject (or the individual) enters the study or begins to be observed or gets a particular treatment.

b) A scale for measuring the passage of time must be considered. In medical research, which usually deals with actual life times , this scale could be for example, hours, days, weeks, months or even years.

c) The meaning of failure should be clearly defined. This means we should identify what we mean by a failure event.

In survival analysis, sometimes we are interested in only the distribution of failure times, for example, in a group of patients. More often we may be interested in comparing the failure times of two (or more) groups of individuals or patients, say one group treated by a Placebo and the other by a new medicine. We wish to investigate the influence of the new medicine in prolonging the patients' survival time. Alternatively, values of potential explanatory variables may be available for each individual from which a model for survival time may be formed. In some survival analyses the researcher may wish to investigate the relation between the explanatory variables and the survival times as well.

5-1-2: Censoring :

An important reason for using specialised statistical models and methods for survival data is to accommodate a problem which arises in recording failure times. In survival data there is the possibility that some individuals or patients may not be observed for the full time to failure. Note, for example, it is impossible or at least very difficult to follow up a group of patients for tens of years to observe their death and record their survival time. In some types of survival analyses it may be impossible to observe the failure event for all individuals or patients. Such a situation happens, for example, when the failure event is death from a particular disease (e.g. heart attack) but there are several other diseases which could cause death. Note someone who has died from Lung Cancer could not have died from the Heart Attack as well. This implies that in survival models, the problem of not being able to record the actual or whole survival time can not be neglected.

The above mentioned difficulty in recording individuals' or patients' survival time is known as a censoring problem. Censoring has led statisticians to develop some particular methods to analyse survival or failure times. Note that when the failure time of a patient is censored, this implies that his/her actual failure time is more than the observed time.

5-1-3 : Failure time distributions :

Let T be a non- negative continuous random variable representing the failure time of an individual from a homogeneous population. The probability model of T can be specified in many ways, three of which are particularly useful in survival applications: the survivor function, the probability density function, and the hazard function. Interrelations between these three representations are given below for both discrete and continuous distributions.

The survival function is defined as the probability that T is at least as great a value as t; that is,

$$S(t)=P(T \geq t), \qquad 0<t<\infty,$$

where t is a possible survival time and S(.) is, the survival function and gives the probabilities in the right tail of the distribution. Clearly S(t) is a monotone non-increasing left continuous function with

$$S(0)=1,$$

and,

$$\lim_{t\to\infty} S(t)=0.$$

The probability density function (p.d.f.) of T is

$$f(t)=\lim_{\Delta t\to 0^+} [P(t\leq T<t+\Delta t)/ \Delta t]$$

$$= -dS(t)/dt.$$

Conversely, $S(t)=\int_t^{\infty} f(s)ds$ and $f(t)\geq 0$ with $\int_0^{\infty} f(t)dt=1$. The range of T as should be the case over $(0, \infty)$.

The hazard function specifies the instantaneous rate of failure at T=t

$$h(t)= \lim_{\Delta t\rightarrow o+}[P(t\leq T<t+\Delta t \mid T\geq t)/ \Delta t]$$

$$=f(t)/S(t).$$

It is easily seen that h(t) specifies the distribution of T since, from the previous equation,

$$h(t)=-d\log S(t)/dt$$

So that integrating and using S(0)=1, we obtain

$$S(t)= \exp(-\int_0^t h(u)du)$$

$$= \exp(H(t))$$

where H(t) is called the cumulative hazard function.

The p.d.f can then be written as

$$f(t)=h(t) \exp(-\int_0^t h(u)du).$$

5-1-4: Different type of survival models :

Many types of survival models have been introduced in the last two decades. Here we do not intend to mention or to discuss all of them. In this section we just mention two main groups of survival models and then in the next section we will introduce more precisely the (survival) model which is intended to be used in this research. Two main types of survival models are usually considered, parametric and non parametric survival models. Parametric survival models are those for which some assumptions about the distribution of the failure (survival) times are made in advance; for example, that the failure times are exponentially distributed or that they have a Weibull distribution. Accelerated failure time models and Log duration survival models are two examples of parametric survival models. The other type of survival models are those under which no assumption is made about the distribution of survival times i.e. we do not assume that the distribution of failure times is a particular distribution.

One of the most famous survival models is the Cox Proportional Hazards model. Since in this research we use this particular model, we now introduce this in more detail.

5-1-5 :Cox Proportional Hazards Models :

As was said, the Cox Proportional Hazards Model or simply the Cox Regression Model is a nonparametric proportional hazards based (survival) model. As is clear from its name, the assumption of "proportional hazards" is a basic assumption in the Cox model. It is a strong assumption which needs to be checked. Later in section 4-5-1 a method for investigating the proportionality of hazards assumption will be introduced.

The Cox Proportional Hazards model proposed by Cox can be written in several different ways of which the most usual is :

$$h(t)=h_0(t)\exp(\underline{\beta}^T \underline{X}),$$

where $h_0(t)$ is an unknown function and is called the baseline hazard function, $\underline{X}$ is a particular set of levels of explanatory variables, $\underline{\beta}$ is the vector of coefficients of the explanatory variables and h(t) is the hazard function which shows the instantaneous hazard of failure at time T= t. Both $h_0(t)$ and $\underline{\beta}$ are estimated from the data. The baseline survival function, the survival function and the density function of the survival time T can be, respectively, written as :

$$S_0(t) =\exp\{-\int_0^t h_0(u)du\}$$

and

$$S(t) = [S_0(t)]^{\exp(\underline{\beta}^T \underline{X})} \quad \text{or} \quad S(t) = \exp\{-\int_0^t h(u)du\}$$

and

$$f(t)=h(t)\,[S_0(t)]^{\exp(\underline{\beta}^T \underline{X})} \quad \text{or} \quad f(t) =h(t)\exp\{-\int_0^t h(u)du\}.$$

Different approaches can be used to estimate the coefficient $\underline{\beta}$ but the most usual approach is the one which is known as the method of partial likelihood as proposed by Cox.

To illustrate what the assumption of proportional hazards really means, suppose that a Cox Proportional Hazards model is fitted to the hazard of failure, using only one explanatory variable, say the sex of patients. Then the proportionality of hazards of failure means that the ratio of the hazards of failure for male and female (two levels of sex) is constant over time. As was mentioned before, this is quite a strong assumption on which to base estimation of hazard functions. Hence it is necessary to check this assumption in respect of any fitted Cox Proportional Hazards model.

5-1-5-1: Checking The Proportional Hazards Assumption :

As was mentioned before, one of the assumptions of a Cox regression model is that for any two cases (e.g. for any two patients), the ratio of the estimated hazard across time is a constant. For example if we have two patients who are similar in all values of the explanatory variables except sex and one of them is male and the another is female, then the proportionality assumption of hazards of failure for these two patients means, the ratio of their estimated hazard rates across all time points is the constant value of e^{β}, where β is the regression coefficient of sex in the fitted Cox Regression model. This is not an assumption to be made lightly.

A useful plot for assessing whether the proportional hazards assumption is valid or not, is the Log-Minus-Log (LML) of the survival function plot. If the hazards of failure for two levels of one explanatory variable, say for male and female, is proportional, then the plot of the logarithm of minus the logarithm of the estimated survival functions corresponding to different levels of the explanatory variable (e.g. for male and females) against survival times should be parallel. The survival function at each level of the explanatory variable can be estimated using the Kaplan-Meier method. The mathematical expression for this property is as follows:

We show the property only for the case when a single explanatory variable is included in the Cox Proportional hazards model. Suppose a Cox Proportional Hazards model is fitted to the survival time T (T is a non negative random variable) of some individuals, using an explanatory variable X having two

possible levels $X= x_1$ and $X= x_2$ (say code zero for male individuals and code 1 for females). Then the fitted Cox model could be written as,

$$h(t)=h_0(t)\exp(\beta X),$$

where $h_0(t)$ is the baseline hazard function (the hazard at X=0), β is the coefficient of the explanatory variable X in the model, X is either x_1 or x_2 and h(t) is the hazard function which shows the instantaneous hazard of failure at time T= t. Note that the hazard functions for those individuals whose value of the explanatory is x_1 or x_2 could be written, respectively, as

$$h(t|x_1)=h_0(t)\exp(\beta x_1),$$

$$h(t|x_2)=h_0(t)\exp(\beta x_2),$$

and the related survival functions to each of the above hazard functions could be written as,

$$S(t|\, x_1) = [S_0(t)]^{\exp(\beta x_1)}.$$

Similarly for the survival function of those individuals whose value of explanatory variable is x_2, could be written as

$$S(t|x_2) = [S_0(t)]^{\exp(\beta x_2)},$$

using a general formula derived three pages earlier.

Note then,

$$\text{Log}[S(t|\, x_1)]= \text{Log}\, \{[S_0(t)]^{\exp(\beta x_1)}\}$$

$$= \exp(\beta x_1)\, .\, \text{Log}\, [S_0(t)]$$

Since $S(t|\, x_1)$ is always less than 1 we multiply it by a minus sign in order to take logs again to give

$$\text{Log}\, \{-\text{Log}[S(t|\, x_1)]\} = \text{Log}\, -\{\exp(\beta x_1)\, .\, \text{Log}\, [S_0(t)]\}$$

$$= \beta x_1 + \text{Log}\{-\, \text{Log}\, [S_0(t)]\}.$$

Similarly it can be shown that,

$$\text{Log}\{-\text{Log}[S(t|\, x_2)]\} = \beta\, x_2 + \text{Log}\{-\text{Log}[S_0(t)]\}.$$

Note that the difference between

$$C = \text{Log}\{-\text{Log}[S(t|\, x_1)]\}$$

and

$$D = \text{Log}\{-\text{Log}[S(t|\, x_2)]\}$$

is $\beta(x_1-x_2)$. Since x_1 and x_2 are constant over time, therefore the difference between C and D is always constant i.e. the two functions

$$C = \text{Log}\{-\text{Log}[S(t|\, x_1)]\}$$

and

$$D = \text{Log}\{-\text{Log}[S(t|\, x_2)]\}$$

are parallel over time t. Note that this result is obtained from a Cox Proportional Hazards model for which the proportionality assumption of hazards is adopted. This implies that if it is discovered that the Log Minus Log (LML) plot of the survival functions corresponding to two or more levels of an explanatory variable are parallel (over time t) then it can be assumed that the hazards of failure for the individuals at different levels of the explanatory variable, at any particular time, is proportional. In this research the Log Minus Log plot of survival functions against the survival times (LML plot), has been used to investigate the validity of the proportional hazards assumption. For this purpose survival functions will be estimated by the Kaplan-Meier method.

5-1-5-2 : Methods for Checking The Goodness of Fit of The Cox Proportional Hazards Model :

In this research it is also intended to investigate the goodness of fit of all fitted Cox Proportional Hazard models by studying residuals. One definition is:

$$H(t|\underline{x})=H_0(t)\, e^{\underline{\beta}^T\underline{X}} \qquad (1)$$

this should have a unit exponential distribution. We will explain why this is the case then how we will investigate whether the estimated residuals, which are defined as above, have or have not the unit exponential distribution. But before going through this, we introduce the Cox-Snell residuals. Note that in the above quantity, $H(t|\underline{X})$ is the cumulative hazard function for an individual with the vector of explanatory variables of $\underline{X}$, while $\underline{\beta}$ is the vector of parameters.

a) Residuals in General (Cox-Snell Residuals in particular):

Residuals are usually defined in connection with linear models. Here a general definition of residuals proposed by Cox and Snell (Cox D.R., Snell E.J. (1968)), and known as the Cox-Snell residuals, will be presented. In the context of normal-theory linear model, an $n\times 1$ vector of random variables $\underline{Y}$ is assumed to have the form

$$\underline{Y}= X\underline{\beta}+\underline{\varepsilon},$$

where X is a known matrix, $\underline{\beta}$ a vector of unknown parameters and $\underline{\varepsilon}$ an $n\times 1$ vector of unobserved random variables of zero mean, independently normally distributed with constant variance. If $\underline{\hat{\beta}}$ is the vector of least-squares estimates of $\underline{\beta}$, the residuals R* are defined by

$$R^* = \underline{Y} - X\underline{\hat{\beta}} \qquad (2)$$

Provided that the number of parameters is small compared with n, most of the properties of R* are nearly those of ε, i.e. R* should have approximately the properties of a random sample from a normal distribution.

In keeping with (2), more general residuals are defined below (Cox and Snell(1968)). Consider a model expressing an observed vector random variable Y in terms of a vector β of unknown parameters and a vector ε of independently and identically distributed unobserved random variables. More particularly we assume that each observation Y_i depends on only one of the ε's, so that we can write

$$Y_i = g_i(\beta, \varepsilon_i) \quad (i=1, 2, ..., n). \qquad (3)$$

This assumption excludes applications to time series and also to component of variance problems in which several random variables enter into each observation.

To define the residuals (i.e. Cox-Snell residuals) , let $\hat{\beta}$ be the maximum likelihood estimate of β from Y. It would be possible to work with other asymptotically efficient estimates, or even with inefficient estimates. Now suppose that the equation

$$Y_i = g_i(\hat{\beta}, \varepsilon_i)$$

has a unique solution for ε_i , namely

$$e_i = h_i(Y_i , \hat{\beta}). \qquad (4)$$

Note that

$$\varepsilon_i = h_i(Y_i , \beta).$$

We take (4) as defining the residuals corresponding to Y_i and the model (3). It known as a crude residual or Cox-Snell residual.

Note that according to the above definition, in the context of a survival time $Y_i = T_i$,

$$\varepsilon_i = H_i(T_i) = H_0(T_i)e^{\underline{\beta}^T \underline{X}_i} \qquad i=1, 2, ..., n$$

is a generalised residual for individual i (e.g. Lagakos S.W. 1980). Hence ε_i can be estimated by

$$e_i = \hat{H}_i(t_i) = \hat{H}_0(t_i) \exp(\underline{\hat{\beta}}^T \underline{X}_i) \qquad i=1, 2, ..., n \quad (5)$$

where $\underline{\hat{\beta}}$ is the maximum likelihood estimator of β and $H_0(ti)$ is the cumulative baseline hazard function for individual i with covariate values $\underline{X}_i$. Note that e_i is right-censored when T_i is right-censored.

b) Distribution of e_i :

We now show that under the Cox proportional hazards model the Cox-Snell residuals have a unit exponential distribution

$$e_i = \hat{H}_0(t_i) \exp(\underline{\hat{\beta}}^T \underline{X}_i).$$

Suppose the random variable T has the density function f(t), distribution function F(t) and survival function S(t) with S(0)=1 let

$$h(t)=f(t)/S(t)$$
$$= -S'(t)/S(t)$$
$$= -d\{\ln[S(t)]\}/dt.$$

Hence,

$$H(t)=\int_0^t h(u)\, du$$
$$=\int_0^t (-d\{\ln[S(u)]\}/du)\, du$$

$$= \{-\ln[S(u)]\}_0^t$$

$$= -\ln[S(t)] - [-\ln[S(0)]]$$

and since $[-\ln[S(0)]] = 0$, therefore

$$H(t) = -\ln[S(t)].$$

Now consider the cumulative distribution of $H=H(T)$

$$F_H(h)=P(H\leq h),$$

Take $U=S(T)$. Then we have $H=-\ln(U)$. Hence

$$F_H(h)=P(-\ln(U)\leq h)$$

$$=P(\ln(U)\geq -h)$$

$$=P(U\geq \exp(-h))$$

$$=1-P(U\leq \exp(-h))$$

$$=1-P(U\leq u), \text{ where } u=\exp(-h).$$

and since $U= S(T)$ is uniform $(0 , 1)$ then it implies $P(U\leq u)=u$, therefore

$$F_H(h)=1-u$$

where $u=\exp(-h)$. This implies

$$=F_H(h)=1-\exp(-h).$$

This is the cumulative distribution of unit exponential distribution. Hence

$$f_H(h)=F'_H(h)$$

$$=d[1-\exp(-h)]/dh$$

$$=e^{-h}$$

Which is the Ex(1) p.d.f.

This argument extends approximately to $e_i = \hat{H}(T_i \mid \underline{X}_i)$

$$= \hat{H}_0(T_i)\exp(\hat{\underline{\beta}}^T \underline{X}_i)$$

$$= \ln \hat{S}(T_i \mid \underline{X}_i)$$

c) Use of $e_i = \hat{H}_0(t_i) \exp(\hat{\underline{\beta}}^T \underline{X}_i)$ in investigating the goodness of fit of the Cox Proportional Hazards model :

Hence the overall fit of the Cox Proportional Hazards model can be assessed by investigating whether the estimated values of the $e_1, e_2, ..., e_n$ have the unit exponential distribution or not. Note that the estimation of e_i can be obtain by

$$\hat{e}_i = \hat{H}_0(t_i) \exp(\hat{\underline{\beta}}^T \underline{X}_i).$$

Since $\hat{e}_i$ can be either complete or censored therefore the above mentioned assessment can be done by using the tools developed for survival analyses. It is necessary to estimate the log 'survival' function or the cumulative hazard function of the residuals $\hat{e}_i$. If $\hat{e}_i$ has an unit exponential distribution then the plot of the log survival function of the residuals or the cumulative hazard function of the residuals against the residuals themselves should be, a straight line having an inverse relation with the residuals(slope of -45^0) or a straight 450 degree line through the origin. This idea comes from the fact that for the unit exponential distribution we have

$$S(e)=\exp(e)$$

and therefore,

$$\text{Log } S(e)=e$$

5-2 : Modelling first time free of admission :

Recall that first time free of admission is time interval between date of first discharge (from hospital) and the next admission date. Note we have considered only those patients whose type of first admissions are type 2.

Table 5-2-1 shows the final Cox Proportional Hazards model which is fitted to the first time free of admission. The factors "Age", "Sex", "Year" and "City" which are presented in this model are known from previous chapters. All these factors have been measured at the time of first admission. The only new covariate which appeared in this model is "length of stay" in hospital. This covariate, which is measured in days and is a continuous covariate, shows how long the patient has spent in hospital. The factor "Age" has 5 levels which are coded as 1 to 5 and are, respectively, corresponding to 0-2, 3-6, 7-14, 15-25 and "more than 25" years old patients. The factor "Year" has 9 levels which are corresponded to year 1984 to 1992. The factor "City" has 7 levels which are coded as 1 to 7 and are, respectively, corresponding to Aberdeen, Dundee, Edinburgh, Glasgow, Kilmarnock, Paisley and Motherwell. A stepwise approach was used to enter the covariates in the model and the change in log likelihood was chosen to be the index for entering the covariates. All the above mentioned covariates and all their 2-factor interaction terms were candidates for entering into the model. The final model is shown in table 5-2-1. It should be mentioned that the basic category for all covariates (except "len_stay" which is a continues variable) is the first category.

Model of table 5-2-1 indicates that all above mentioned covariates and the interactions between "Age" and the factors "Sex", "Year" and "City" are

significantly related to first time free of admission. There has been a total change of 1237.355 (d.f. = 80) in log likelihood (P<.0001) and the model has 80 parameters. The order of entering the covariates and their interaction terms are, "Age", "length of Stay" in hospital, "Year"*""Age", "Year", "City", "Sex", "sex"*"Age" and "City"*"Age". The model, considering the change in log likelihood (which is not shown in table 5-2-1) and the Wald statistic, indicates that the most important covariates which are related to first time free of admission are "Age" and "Length of Stay" in hospital. The next important factors are "Sex" of patients and the interaction between "Age" and "Sex". Note that even the factors such as "Year" and "City" and the interaction between "Year" and "Age" are entered in the model (i.e. are significantly related to first time free of admission) but, considering the change that they have made in log likelihood and their degree of freedom, they are not really important. It implies that this result is consistent with what we discovered in chapter 4. Recall that in chapter 4 we discovered that the number of later admissions, of those patients whose first admissions are type 2, are significantly related to two factors "Age", "Sex" and the interaction between these two factors. The factor "Year" was just about significant.

Table 5-2-1 : Cox Proportional Hazard model fitted to first time free of admission.

-2 Log Likelihood (initial): 156802.411
-2 Log Likelihood : 155565.056

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	1237.355	80	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Age			709.9998	4	<.0001	
Age(2)	-.4654	.0384	146.6783	1	<.0001	.6279
Age(3)	-.9546	.0516	342.0641	1	<.0001	.3850
Age(4)	-.9725	.0528	338.7876	1	<.0001	.3781
Age(5)	-.7447	.0356	437.0700	1	<.0001	.4749

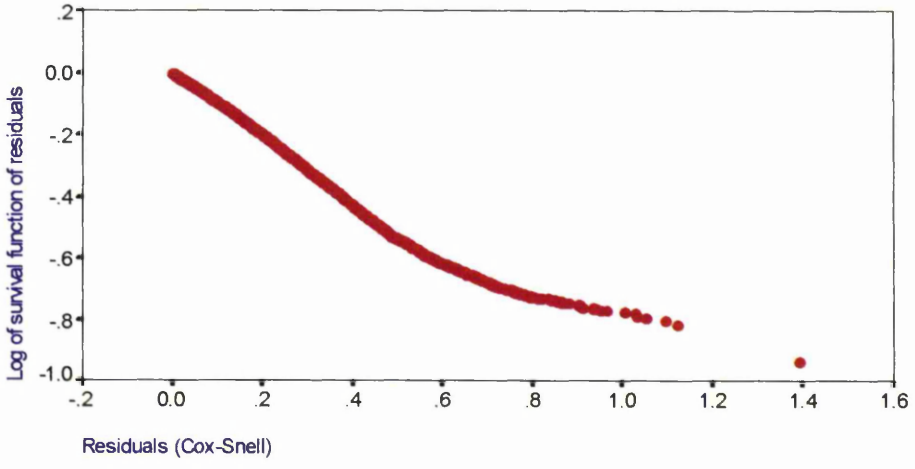
SEX	.1380	.0274	25.2903	1	<.0001	1.1479
Year			41.2342	8	<.0001	
Year(2)	-.0857	.0502	2.9225	1	.0874	.9178
Year(3)	-.0502	.0518	.9373	1	.3330	.9511
Year(4)	-.1965	.0518	14.4051	1	.0001	.8216
Year(5)	-.1043	.0512	4.1537	1	.0415	.9010
Year(6)	-.1368	.0526	6.7731	1	.0093	.8721
Year(7)	-.1156	.0525	4.8443	1	.0277	.8908
Year(8)	-.2974	.0579	26.4176	1	<.0001	.7427
Year(9)	-.2942	.0748	15.4662	1	.0001	.7451
City			16.2464	6	.0125	
City(2)	.1069	.0586	3.3253	1	.0682	1.1129
City(3)	.1650	.0479	11.8488	1	.0006	1.1794
City(4)	.0498	.0464	1.1546	1	.2826	1.0511
City(5)	.0655	.0580	1.2749	1	.2588	1.0677
City(6)	.1197	.0565	4.4903	1	.0341	1.1271
City(7)	.0920	.0581	2.5069	1	.1134	1.0964
LEN_STAY	.0374	.0030	157.5903	1	<.0001	1.0382
Age*SEX			24.5613	4	.0001	
Age(2)*SEX	.0652	.0676	.9296	1	.3350	1.0674
Age(3)*SEX	.1636	.0893	3.3570	1	.0669	1.1777
Age(4)*SEX	.3684	.0904	16.6002	1	<.0001	1.4454
Age(5)*SEX	-.0429	.0590	.5285	1	.4672	.9580
Year*Age			117.5984	32	<.0001	
Year(2)*Age(2)	-.1302	.1398	.8673	1	.3517	.8779
Year(3)*Age(2)	-.0923	.1344	.4721	1	.4920	.9118
Year(4)*Age(2)	-.3604	.1284	7.8801	1	.0050	.6974
Year(5)*Age(2)	-.1336	.1289	1.0740	1	.3000	.8749
Year(6)*Age(2)	-.2090	.1364	2.3476	1	.1255	.8114
Year(7)*Age(2)	-.2576	.1262	4.1639	1	.0413	.7729
Year(8)*Age(2)	-.4953	.1358	13.3084	1	.0003	.6094
Year(9)*Age(2)	-.4914	.1607	9.3510	1	.0022	.6118
Year(2)*Age(3)	.1639	.1652	.9845	1	.3211	1.1781
Year(3)*Age(3)	-.2292	.1780	1.6574	1	.1980	.7952
Year(4)*Age(3)	-.7023	.1710	16.8742	1	<.0001	.4955
Year(5)*Age(3)	-.1795	.1661	1.1689	1	.2796	.8356
Year(6)*Age(3)	-.3036	.1743	3.0327	1	.0816	.7382
Year(7)*Age(3)	-.3328	.1724	3.7259	1	.0536	.7169
Year(8)*Age(3)	-.5151	.1760	8.5644	1	.0034	.5974
Year(9)*Age(3)	-.8064	.2427	11.0389	1	.0009	.4465
Year(2)*Age(4)	-.1413	.1662	.7226	1	.3953	.8682
Year(3)*Age(4)	-.0796	.1649	.2328	1	.6295	.9235
Year(4)*Age(4)	-.6076	.1683	13.0268	1	.0003	.5447
Year(5)*Age(4)	-.2159	.1670	1.6719	1	.1960	.8058
Year(6)*Age(4)	-.1664	.1656	1.0097	1	.3150	.8467
Year(7)*Age(4)	-.3506	.1654	4.4913	1	.0341	.7042
Year(8)*Age(4)	-.7885	.1940	16.5230	1	<.0001	.4545
Year(9)*Age(4)	-.8735	.2329	14.0669	1	.0002	.4175
Year(2)*Age(5)	.0584	.1192	.2404	1	.6239	1.0602
Year(3)*Age(5)	-.1024	.1201	.7271	1	.3938	.9026
Year(4)*Age(5)	-.1621	.1126	2.0709	1	.1501	.8503
Year(5)*Age(5)	-.1834	.1148	2.5495	1	.1103	.8325
Year(6)*Age(5)	-.2518	.1179	4.5627	1	.0327	.7774

Year(7)*Age(5)	-.5286	.1172	20.3376	1	<.0001	.5894
Year(8)*Age(5)	-.3136	.1178	7.0915	1	.0077	.7308
Year(9)*Age(5)	-.7425	.1412	27.6429	1	<.0001	.4759
City*Age			46.6427	24	.0037	
City(2)*Age(2)	.0077	.1544	.0025	1	.9604	1.0077
City(3)*Age(2)	-.1357	.1216	1.2460	1	.2643	.8731
City(4)*Age(2)	.0734	.1157	.4017	1	.5262	1.0761
City(5)*Age(2)	-.0408	.1428	.0816	1	.7752	.9600
City(6)*Age(2)	.2444	.1370	3.1852	1	.0743	1.2769
City(7)*Age(2)	.1942	.1428	1.8478	1	.1740	1.2143
City(2)*Age(3)	.0930	.1936	.2307	1	.6310	1.0975
City(3)*Age(3)	-.2970	.1600	3.4434	1	.0635	.7430
City(4)*Age(3)	-.0989	.1528	.4189	1	.5175	.9058
City(5)*Age(3)	-.4858	.1905	6.5007	1	.0108	.6152
City(6)*Age(3)	-.1977	.1837	1.1580	1	.2819	.8206
City(7)*Age(3)	-.2138	.1916	1.2450	1	.2645	.8075
City(2)*Age(4)	-.1969	.1841	1.1438	1	.2848	.8213
City(3)*Age(4)	-.3485	.1452	5.7635	1	.0164	.7058
City(4)*Age(4)	-.2871	.1421	4.0821	1	.0433	.7504
City(5)*Age(4)	-.4403	.1844	5.7019	1	.0169	.6438
City(6)*Age(4)	-.2504	.1817	1.8996	1	.1681	.7785
City(7)*Age(4)	-.2747	.1868	2.1619	1	.1415	.7598
City(2)*Age(5)	-.0833	.1299	.4116	1	.5212	.9200
City(3)*Age(5)	-.3827	.0986	15.0752	1	.0001	.6820
City(4)*Age(5)	-.2475	.0960	6.6414	1	.0100	.7808
City(5)*Age(5)	-.2775	.1215	5.2211	1	.0223	.7577
City(6)*Age(5)	-.1834	.1215	2.2781	1	.1312	.8325
City(7)*Age(5)	-.2408	.1283	3.5206	1	.0606	.7860

Model 5-2-1 indicates that babies (age group 1) are at highest risk of having a second admission (i.e. shorter first time free of admission). The model indicates also that females have shorter first time free of admission than males i.e. they return to hospital, as second admission, sooner than males (note that the interaction between "Age" and "Sex" is significant i.e. the inference may change across the age groups). Note these results match with results of chapter 4. In overall, these results are consistent with the results of chapter 4. Recall that in chapter 4 we discovered that number of later asthma admissions of those patients whose first admissions were type 2, was related to age group, sex, the interaction between age and sex and, marginally to, year of first admission. Note that here we are talking only about the hazard of occurrence of second

admission and not all later admissions, therefore some minor differences in results are expected.

Plot 5-2-1 : Plot of log of survival function of residuals of model of table 5-2-1 against the residuals.



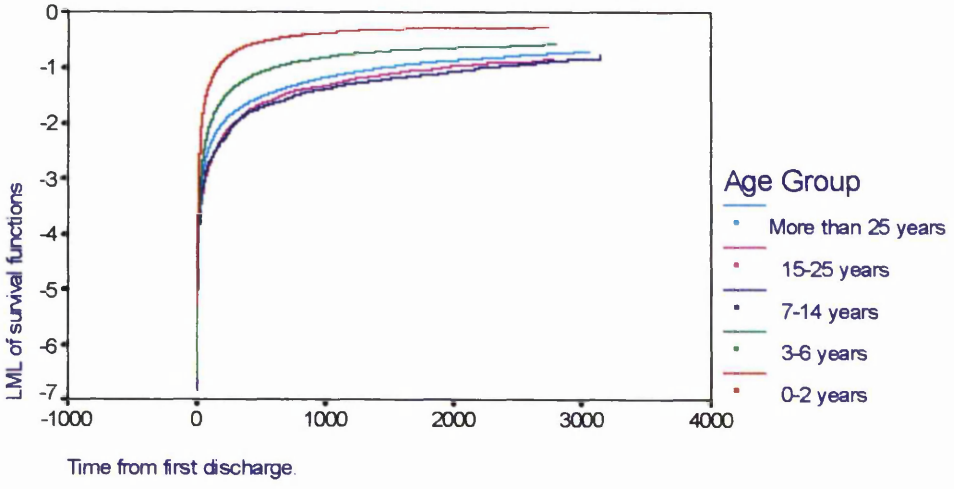
As it was mentioned in section 5-1-5-1, the Cox-Snell residuals were used to carry out an overall test of goodness of fit for model of table 5-2-1. Plot 5-2-1 shows the plot of log of survival function of Cox-Snell residuals for model 5-2-1 against the residuals themselves. Even though the plot shows that relatively large residuals are not exponentially distributed with parameter 1 but for rest of residuals, the plot indicates that the model of table 5-2-1 is fitted well.

To investigate whether hazards are or are not proportional in different levels of different factors, we considered each of factors "Age", Year" and "City", one at each time, as strata and then the Log Minus Log plot of corresponding survival functions were prepared. Note that when any of factors is used as strata then all other significant covariates (and their possible significant interaction terms) were included in the model.

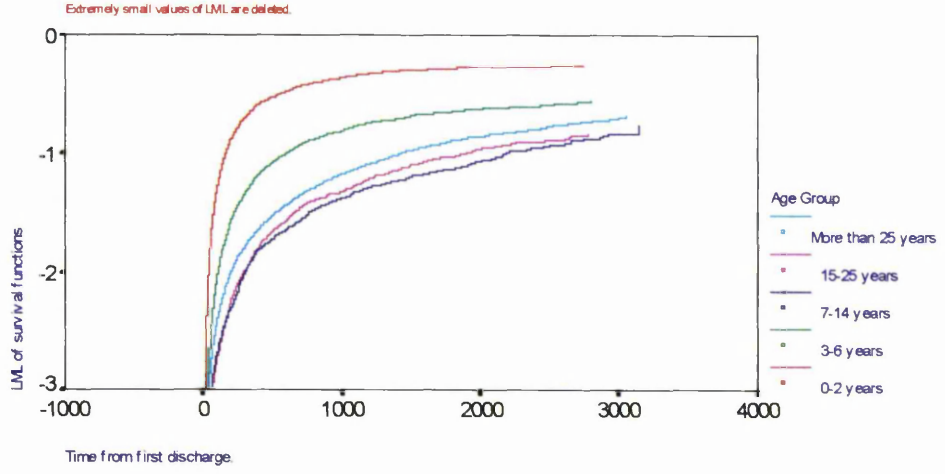
Plot 5-2-2 shows the LML plot corresponding to model of table 5-2-1 when the factor "Age" is as strata and the model is constructed using all other

significant covariates plus their possible significant interactions. Even though the plot indicates that the hazards of failure (i.e. hazard of having the second admission) for age group 3 (7-14 years old) and 4 (15-25 years old) are not proportional but it shows that for other age groups this assumption is valid.

Plot 5-2-2 : LML plot of survival functions when age is as strata in model 5-2-1 and all other sig. cov. are in the model.



Plot 5-2-3 : LML plot of survival functions when age is as strata in model 5-2-1 and all other sig. cov. are in the model.

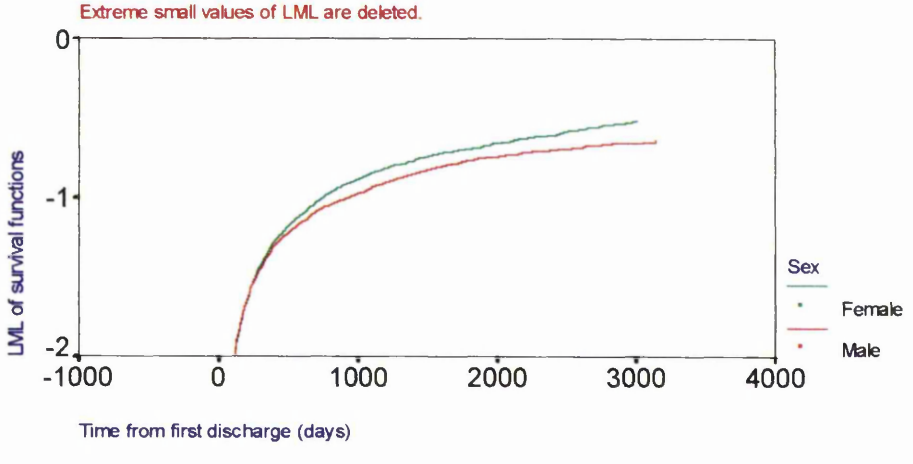


Note that even for age group 3 and 4 also the violation to the proportionality assumption is not very serious. It seems that the hazard functions corresponding to these two age groups appear to be similar (i.e. having common hazard

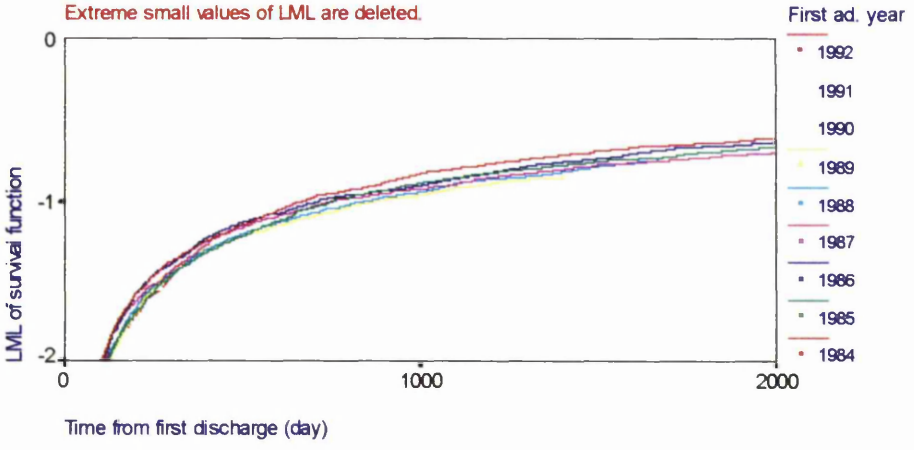
function) rather than being different and then crossing each other. Plot 5-2-3 is similar plot as 5-2-2 but is has been prepared in a bigger scale to be able to investigate the nonproportionality of hazards of groups 3 and 4 better.

Plot 5-2-4 to 5-2-6 show the LML plot of survival functions against survival time when, respectively, "Sex", "Year" and "City" are as strata. Plot 5-2-4 indicates that hazards in different level of factors "Sex" are proportional while plots 5-2-5 and 5-2-6 show that this assumption, for some levels of "Year" and "City", is not valid. Plots 5-2-6 suggests that the proportionality assumption of hazards for cities Aberdeen, Edinburgh, Glasgow and Kilmarnock holds while for other cities it doesn't. Note that, comparing with the effects of "Age" and "Length of stay" in hospital, neither the effect of "Year" nor "City" (on hazards of having second admission) is important. It suggests even the proportionality assumption of hazards is not valid for all levels of the factors "Year" and "City" but it does not really make the results of model 5-2-1 unreliable.

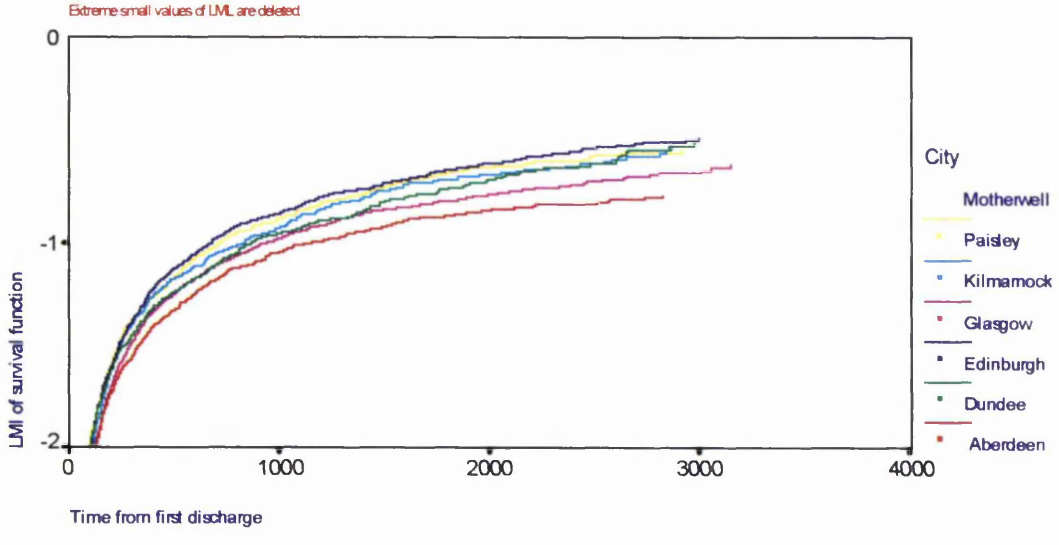
Plot 5-2-4 : LML plot of survival functions when sex is as strata in model 5-2-1and all other sig. cov. are in model.



Plot 5-2-5 : LML of survival functions when year is as strata in model 5-2-1 and all other sig. cov. are in model.



Plot 5-2-6 : LML of survival functions when city is as strata in model 5-2-1 and all other sig. cov. (except age*year) are in model.



Recall that we discovered some violation for proportionality assumption for age group 3 and 4 (plot 5-2-2). We decided to pool these two age groups and fit a Cox-Proportional Hazard model to first time free of admission using all previous covariates plus the factor "Age" with its new levels. This model is shown in table 5-2-2. Note that in this model the factor "Age" has 4 levels

which are 0-2, 3-6, 7-25 and more than 25 years old. Hence the results are consistent with results of table 5-2-1. Plot 5-2-7 which shows the log of survival function of Cox-Snell residuals (of model 5-2-2) against the residuals, indicates that this new model is fitted as well as the previous model. Plot 5-2-8 suggests that the hazards of failure (i.e. hazard of having second admission) in different levels of "Age" (new levels) are clearly proportional. Model 5-2-2 together with plots 5-2-7 and 5-2-8 suggest that model 5-2-1 is reliable.

Table 5-2-2 : Cox Proportional Hazard model fitted to first time free of admission. Age groups 3 and 4 are pooled

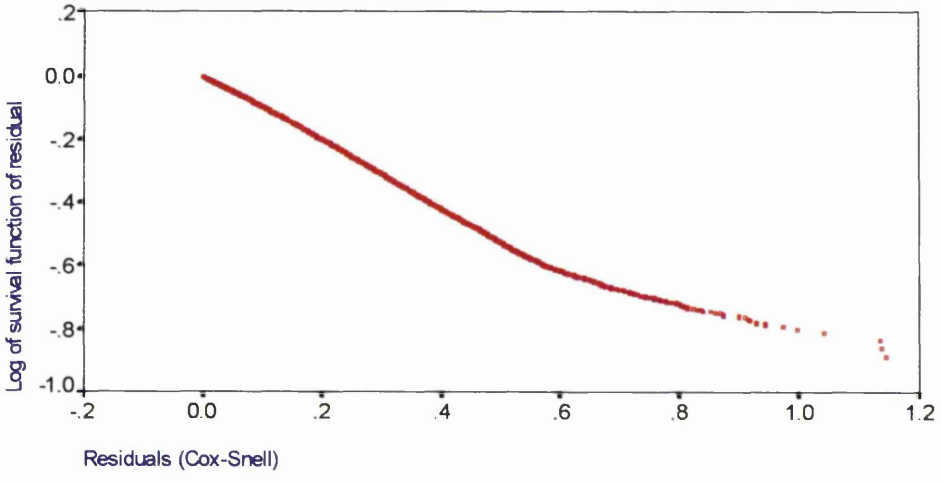
-2 Log Likelihood (initial): 156802.411
-2 Log Likelihood : 155580.407

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	1222.004	64	P<.0001

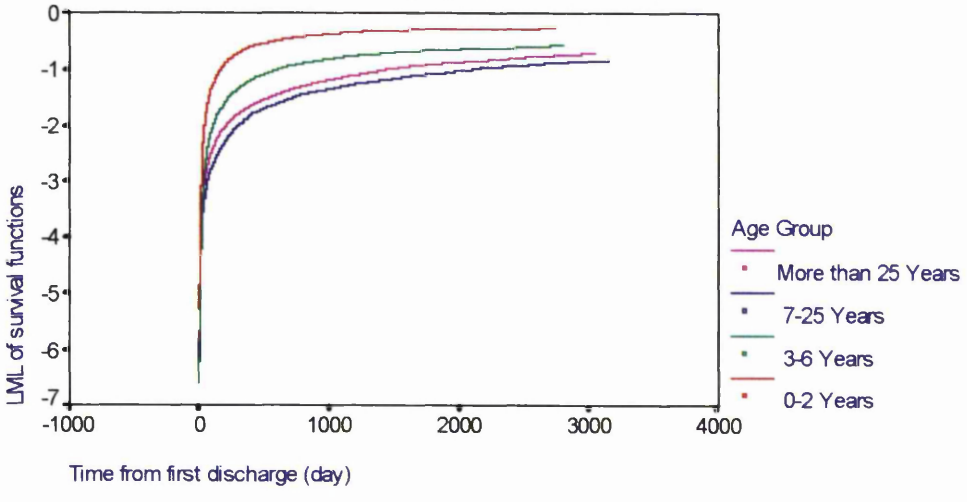
Variable	B	S.E.	Wald	df	Sig	Exp(B)
AGE			712.2319	3	<.0001	
AGE(2)	-.4654	.0384	146.6423	1	<.0001	.6279
AGE(3,4)	-.9479	.0398	568.0334	1	<.0001	.3876
AGE(5)	-.7450	.0356	437.4034	1	<.0001	.4747
SEX	.0977	.0239	16.7539	1	<.0001	1.1027
YEAR			31.2350	8	.0001	
YEAR(2)	-.0938	.0465	4.0689	1	.0437	.9104
YEAR(3)	-.0348	.0468	.5528	1	.4572	.9658
YEAR(4)	-.1243	.0460	7.3099	1	.0069	.8831
YEAR(5)	-.0918	.0461	3.9728	1	.0462	.9123
YEAR(6)	-.1242	.0477	6.7657	1	.0093	.8832
YEAR(7)	-.1029	.0469	4.8069	1	.0283	.9022
YEAR(8)	-.2360	.0506	21.7770	1	<.0001	.7898
YEAR(9)	-.2297	.0638	12.9699	1	.0003	.7948
CITY			25.3557	6	.0003	
CITY(2)	.1108	.0532	4.3263	1	.0375	1.1171
CITY(3)	.1884	.0427	19.4949	1	<.0001	1.2074
CITY(4)	.0697	.0412	2.8613	1	.0907	1.0722
CITY(5)	.1178	.0512	5.3004	1	.0213	1.1251
CITY(6)	.1546	.0499	9.6141	1	.0019	1.1672
CITY(7)	.1259	.0516	5.9493	1	.0147	1.1342

LEN_STAY	.0375	.0030	158.5677	1	<.0001	1.0382
AGE*SEX			22.0976	3	.0001	
AGE(2)*SEX	.0652	.0676	.9292	1	.3351	1.0674
AGE(3,4)*SEX	.2603	.0682	14.5484	1	.0001	1.2973
AGE(5)*SEX	-.0429	.0590	.5299	1	.4667	.9580
AGE*YEAR			108.3176	24	<.0001	
AGE(2)*YEAR(2)	-.1302	.1398	.8669	1	.3518	.8780
AGE(3,4)*YEAR(2)	7.985E-05	.1344	.0000	1	1.0000	1.0001
AGE(5)*YEAR(2)	.0585	.1192	.2410	1	.6235	1.0603
AGE(2)*YEAR(3)	-.0923	.1344	.4721	1	.4920	.9118
AGE(3,4)*YEAR(3)	-.1463	.1367	1.1457	1	.2845	.8639
AGE(5)*YEAR(3)	-.1024	.1201	.7262	1	.3941	.9027
AGE(2)*YEAR(4)	-.3604	.1284	7.8794	1	.0050	.6974
AGE(3,4)*YEAR(4)	-.6543	.1336	23.9828	1	<.0001	.5198
AGE(5)*YEAR(4)	-.1620	.1126	2.0687	1	.1504	.8504
AGE(2)*YEAR(5)	-.1336	.1289	1.0738	1	.3001	.8750
AGE(3,4)*YEAR(5)	-.2028	.1320	2.3610	1	.1244	.8165
AGE(5)*YEAR(5)	-.1833	.1148	2.5473	1	.1105	.8325
AGE(2)*YEAR(6)	-.2090	.1364	2.3475	1	.1255	.8114
AGE(3,4)*YEAR(6)	-.2329	.1348	2.9829	1	.0841	.7923
AGE(5)*YEAR(6)	-.2517	.1179	4.5605	1	.0327	.7775
AGE(2)*YEAR(7)	-.2576	.1262	4.1634	1	.0413	.7729
AGE(3,4)*YEAR(7)	-.3381	.1325	6.5135	1	.0107	.7131
AGE(5)*YEAR(7)	-.5285	.1172	20.3345	1	<.0001	.5895
AGE(2)*YEAR(8)	-.4953	.1358	13.3069	1	.0003	.6094
AGE(3,4)*YEAR(8)	-.6346	.1422	19.9129	1	<.0001	.5302
AGE(5)*YEAR(8)	-.3135	.1178	7.0884	1	.0078	.7309
AGE(2)*YEAR(9)	-.4914	.1607	9.3511	1	.0022	.6118
AGE(3,4)*YEAR(9)	-.8381	.1794	21.8237	1	<.0001	.4325
AGE(5)*YEAR(9)	-.7425	.1412	27.6400	1	<.0001	.4759
AGE*CITY			43.3084	18	.0007	
AGE(2)*CITY(2)	.0077	.1544	.0025	1	.9603	1.0077
AGE(3,4)*CITY(2)	-.0526	.1486	.1255	1	.7231	.9487
AGE(5)*CITY(2)	-.0835	.1299	.4127	1	.5206	.9199
AGE(2)*CITY(3)	-.1357	.1216	1.2460	1	.2643	.8731
AGE(3,4)*CITY(3)	-.3191	.1175	7.3749	1	.0066	.7268
AGE(5)*CITY(3)	-.3828	.0986	15.0811	1	.0001	.6819
AGE(2)*CITY(4)	.0733	.1157	.4017	1	.5262	1.0761
AGE(3,4)*CITY(4)	-.1944	.1133	2.9441	1	.0862	.8233
AGE(5)*CITY(4)	-.2474	.0960	6.6400	1	.0100	.7808
AGE(2)*CITY(5)	-.0407	.1428	.0814	1	.7754	.9601
AGE(3,4)*CITY(5)	-.4677	.1450	10.4059	1	.0013	.6264
AGE(5)*CITY(5)	-.2775	.1215	5.2204	1	.0223	.7577
AGE(2)*CITY(6)	.2444	.1370	3.1845	1	.0743	1.2769
AGE(3,4)*CITY(6)	-.2312	.1412	2.6800	1	.1016	.7936
AGE(5)*CITY(6)	-.1834	.1215	2.2793	1	.1311	.8324
AGE(2)*CITY(7)	.1942	.1428	1.8474	1	.1741	1.2143
AGE(3,4)*CITY(7)	-.2460	.1477	2.7738	1	.0958	.7819
AGE(5)*CITY(7)	-.2409	.1283	3.5228	1	.0605	.7860

Plot 5-2-7 : Plot of log of survival function of residuals (Cox-Snell) against the residuals for model 5-2-2.



Plot 5-2-8 : LML plot of survival functions when Age is as strata and all other sig. cov. are in model. Age groups 3 and 4 are pooled.



5-3 : Modelling Second Time Free of Admission ::

In this section we intend to fit a Cox Proportional hazard model to second time free of admission. Recall that second time free of admission is defined as time interval between second discharge from hospital and third admission. Second time free of admission can be measured only for those patients which second asthma admission has already occurred i.e. the group of patients being considered for analyses in this section are those who have returned to hospital at least once after first admission and are at risk of being admitted for second time after first admission. These are 8145 patients of which 7825 second times free of admission valid for analyses. For 4033 of these patients, the second times were completed (48.5%) and rest of them (51.5%) were censored times.

In dealing with second time free of admission, two new covariates, which later we show that both are very important covariates, should be considered. These are previous time free of admission and previous length of stay in hospital. Note since we are considering second time free of admission, these covariates are actually "First time free of admission" and "First length of stay in hospital". In section 5-2 we mentioned and used the covariate "First length of stay" called only as "Length of stay". In table 5-3-1 and 5-3-2 two frequency tables corresponding to "First time free of admission" and recent "Length of stay" are shown.

Table 5-3-1 : Frequency of complete first time free of admission

First time free of admission	Frequency	Percentage
Less than a month	1285	15.8
2-6 months	2746	33.7
6 months to one year	1406	17.3
Between 1 and 2 years	1271	15.6
Between 2 and 3 years	599	7.4
More than 3 years	838	10.3
Total	8145	

Table 5-3-2 : Frequency of second length of stay in hospital.

Length of stay in hospital	Frequency of patients	Percentage
up to one week	7106	87.2
8-14 days	823	10.1
15-21 days	159	2.0
22-28 days	36	0.4
More than 4 weeks.	21	0.3
Total	8145	

Table 5-3-3 shows the Cox Proportional Hazard model which is fitted to second time free of admission. The main effects of two factors "First Time free of admission" (in abbreviate "first time") and "First Length of stay" in hospital as well as the main effects of previously mentioned factors and their two factor interactions (i.e. "Age", "Sex", "Year" and "City", "Length of stay" and their two factor interactions) were candidates to enter in the model. The Stepwise Method and the likelihood ratio test were used to select the significant covariates. The model includes 70 parameters and the change in initial log likelihood is 654.202.

Table 5-3-3 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2.

Total No. of Cases : 8145
Prop. of Censored : 48.5%
-2 Log Likelihood (initial) : 68144.053
-2 Log Likelihood : 67467.625

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	676.428	85	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-7.06E-04	4.704E-05	225.0975	1	<.0001	.9993
First_len_stay	.0183	.0047	15.0453	1	.0001	1.0185
AGE			98.6919	4	<.0001	
AGE(2)	-.3522	.0551	40.8784	1	<.0001	.7031
AGE(3)	-.5031	.0861	34.1834	1	<.0001	.6046
AGE(4)	-.3105	.0792	15.3724	1	.0001	.7331
AGE(5)	-.4551	.0555	67.3019	1	<.0001	.6344
Len_stay	.0124	.0043	8.3535	1	.0038	1.0125
SEX	-.0473	.0474	.9974	1	.3179	.9538
YEAR			12.6741	8	.1236	
YEAR(2)	-.0375	.0697	.2892	1	.5907	.9632
YEAR(3)	.0173	.0710	.0592	1	.8078	1.0174
YEAR(4)	-.0661	.0737	.8032	1	.3702	.9361
YEAR(5)	-.0162	.0714	.0515	1	.8205	.9839
YEAR(6)	-.1957	.0777	6.3467	1	.0118	.8223
YEAR(7)	-.1629	.0811	4.0326	1	.0446	.8496
YEAR(8)	-.1361	.0924	2.1698	1	.1407	.8727
YEAR(9)	-.0556	.1485	.1403	1	.7080	.9459
CITY			8.9198	6	.1781	
CITY(2)	-.1201	.0866	1.9219	1	.1656	.8868
CITY(3)	-.0016	.0690	.0006	1	.9813	.9984
CITY(4)	-.1001	.0680	2.1705	1	.1407	.9047
CITY(5)	.0571	.0824	.4795	1	.48871	.0587
CITY(6)	-.0271	.0845	.1031	1	.7481	.9732
CITY(7)	.0284	.0833	.1165	1	.7328	1.0289
YEAR*AGE			58.8164	32	.0027	.0000
YEAR(2)*AGE(2)	-.0104	.1789	.0034	1	.9537	.9897
YEAR(3)*AGE(2)	.4076	.1714	5.6559	1	.0174	1.5032
YEAR(4)*AGE(2)	-.1312	.1677	.6116	1	.4342	.8771
YEAR(5)*AGE(2)	.0193	.1678	.0132	1	.9084	1.0195
YEAR(6)*AGE(2)	-.4790	.1868	6.5730	1	.0104	-.6194
YEAR(7)*AGE(2)	-.2989	.1760	2.8825	1	.0895	-.7417
YEAR(8)*AGE(2)	-.1383	.1973	.4912	1	.4834	.8709
YEAR(9)*AGE(3)	-.2261	.2924	.5980	1	.4393	.7976
YEAR(2)*AGE(3)	-.1340	.2386	.3157	1	.5742	.8746
YEAR(3)*AGE(3)	.4045	.2416	2.8014	1	.0942	1.4985

YEAR(4)*AGE(3)	.0660	.2462	.0718	1	.7888	1.0682
YEAR(5)*AGE(3)	-.0802	.2380	.1136	1	.7361	.9229
YEAR(6)*AGE(3)	-.4681	.2605	3.2299	1	.0723	.6262
YEAR(7)*AGE(3)	-.5132	.2874	3.1892	1	.0741	.5986
YEAR(8)*AGE(3)	-.1389	.2817	.2429	1	.6221	.8704
YEAR(9)*AGE(3)	-.1684	.4899	.1182	1	.7310	.8450
YEAR(2)*AGE(4)	.1150	.2161	.2829	1	.5948	1.1218
YEAR(3)*AGE(4)	.0710	.2253	.0993	1	.7527	1.0736
YEAR(4)*AGE(4)	-.2665	.2340	1.2966	1	.2548	.7661
YEAR(5)*AGE(4)	.2085	.2195	.9025	1	.3421	1.2319
YEAR(6)*AGE(4)	-.3964	.2327	2.9009	1	.0885	.6728
YEAR(7)*AGE(4)	.0216	.2247	.0092	1	.9235	1.0218
YEAR(8)*AGE(4)	-.2488	.2974	.7000	1	.4028	.7797
YEAR(9)*AGE(4)	-.1987	.4499	.1951	1	.6587	.8198
YEAR(2)*AGE(5)	-.0870	.1549	.3149	1	.5747	.9167
YEAR(3)*AGE(5)	.0708	.1596	.1971	1	.6571	1.0734
YEAR(4)*AGE(5)	-.1097	.1494	.5389	1	.4629	.8961
YEAR(5)*AGE(5)	-.2935	.1564	3.5238	1	.0605	.7456
YEAR(6)*AGE(5)	-.4101	.1593	6.6305	1	.0100	.6636
YEAR(7)*AGE(5)	-.1332	.1631	.6664	1	.4143	.8753
YEAR(8)*AGE(5)	-.5528	.1749	9.9949	1	.0016	.5753
YEAR(9)*AGE(5)	-.2886	.2490	1.3437	1	.2464	.7493
CITY*AGE			61.4193	24	<.0001	
CITY(2)*AGE(2)	.2281	.2184	1.0909	1	.2963	1.2562
CITY(3)*AGE(2)	-.2087	.1763	1.4013	1	.2365	.8117
CITY(4)*AGE(2)	-.1938	.1661	1.3612	1	.2433	.8239
CITY(5)*AGE(2)	.1649	.1991	.6861	1	.4075	1.1793
CITY(6)*AGE(2)	-.0216	.1887	.0131	1	.9089	.9786
CITY(7)*AGE(2)	-.2836	.1981	2.0486	1	.1523	.7531
CITY(2)*AGE(3)	-.4161	.2926	2.0223	1	.1550	.6596
CITY(3)*AGE(3)	-.1526	.2262	.4551	1	.4999	.8585
CITY(4)*AGE(3)	-.5643	.2230	6.4056	1	.0114	.5687
CITY(5)*AGE(3)	.0683	.2655	.0663	1	.7969	1.0707
CITY(6)*AGE(3)	-.7178	.2836	6.4052	1	.0114	.4878
CITY(7)*AGE(3)	-.4489	.2740	2.6851	1	.1013	.6383
CITY(2)*AGE(4)	.3438	.2608	1.7384	1	.1873	1.4103
CITY(3)*AGE(4)	-.0066	.2071	.0010	1	.9747	.9934
CITY(4)*AGE(4)	-.3699	.2056	3.2359	1	.0720	.6908
CITY(5)*AGE(4)	.0609	.2604	.0547	1	.8151	1.0628
CITY(6)*AGE(4)	-.2978	.2648	1.2655	1	.2606	.7424
CITY(7)*AGE(4)	-.3287	.2598	1.6010	1	.2058	.7199
CITY(2)*AGE(5)	.0771	.1911	.1626	1	.6868	1.0801
CITY(3)*AGE(5)	-.0041	.1435	.0008	1	.9772	.9959
CITY(4)*AGE(5)	-.4138	.1412	8.5907	1	.0034	.6611
CITY(5)*AGE(5)	-.1466	.1807	.6586	1	.4171	.8636
CITY(6)*AGE(5)	-.3418	.1765	3.7530	1	.0527	.7105
CITY(7)*AGE(5)	-.7111	.1868	14.4921	1	.0001	.4911
SEX*LEN_STAY	.0170	.0075	5.0969	1	.0240	1.0172
SEX*CITY			16.2669	6	.0124	
SEX*CITY(2)	-.1189	.1527	.6057	1	.4364	.8879
SEX*CITY(3)	-.1791	.1189	2.2697	1	.1319	.8360
SEX*CITY(4)	.1509	.1150	1.7201	1	.1897	1.1628
SEX*CITY(5)	-.2013	.1445	1.9399	1	.1637	.8177

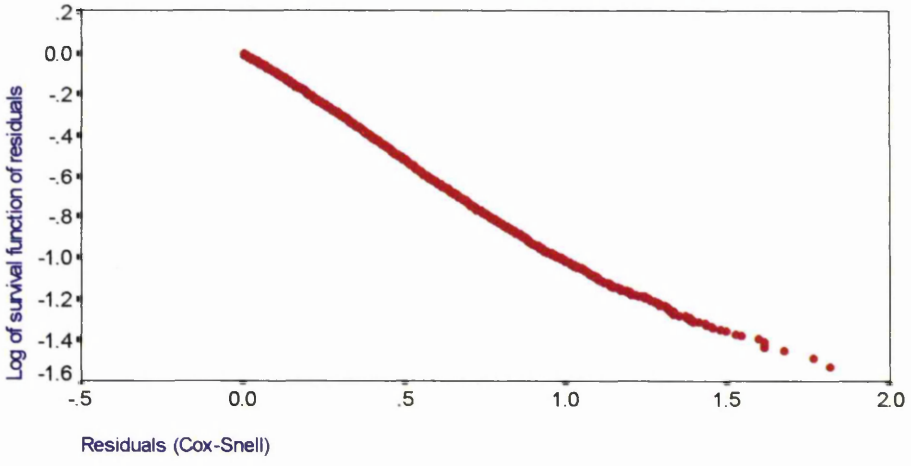
SEX*CITY(6)	-.0062	.1413	.0019	1	.9651	.9938
SEX*CITY(7)	-.0129	.1463	.0078	1	.9296	.9872

Model of table 5-3-3 indicates that second time free of admission is significantly related to previous (first) time free of admission, "Age" at time of first admission, previous (first) length of stay in hospital, the interaction Age*City, recent length of stay in hospital, the interaction Sex*City, the interaction Year*Age and the interaction Sex*Length of stay. These terms were mentioned in order which they were entered in the model. Considering the change in log likelihood (or Wald statistic in model of table 5-3-3) and the related degrees of freedom, none of interaction terms is important. This implies that second time free of admission of asthmatic patients is related to first time free of admission, age of patients and length of stay (both previous and recent ones) in hospital. Model of table 5-3-3 indicates that patients with longer first time free of admission are less at risk of being admitted in hospital as second admission i.e. they have longer second time free of admission as well. Both coefficients of previous (first) and recent length of stay in hospital indicate that the asthmatic patients who have been hospitalised in hospital for a longer time are at more risk than others to be admitted in hospital as the second admission i.e. they have shorter second time free of admission. Later we show that because of some violation to proportionality assumption of hazards in different age groups, the results of model 5-3-3 (particularly those which are corresponding to factor Age) should be reconsidered.

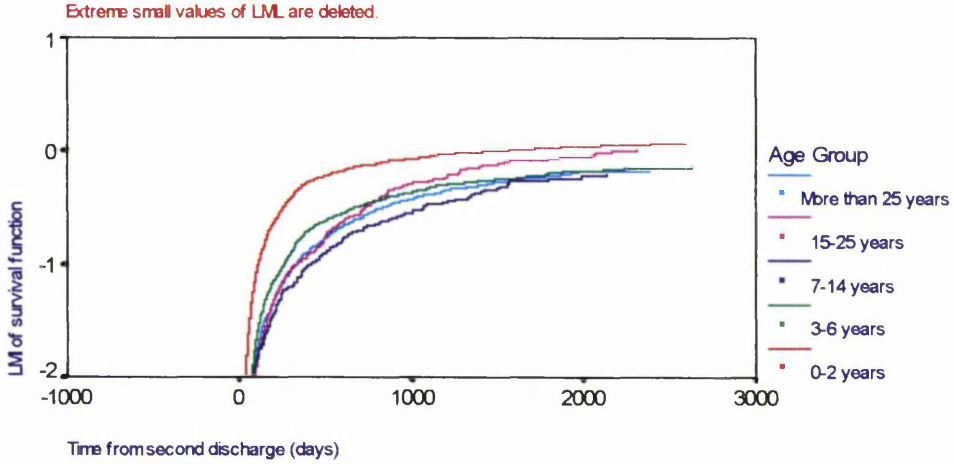
Plot 5-3-1 is the plot of log of survival function of residuals (Cox-Snell Residuals) corresponding to model of table 5-3-3, against the residuals themselves. This plot indicates that residuals are exponentially distributed with parameter 1 i.e. model of table 5-3-3 is fitted well. Plot 5-3-2 is the Log Minus Log plot corresponding to covariate "Age". This plot shows the LML of

survival functions in different levels of factor "Age". Plot 5-3-2 indicates that there is violation to proportionality assumption of hazards for factor "Age". Note that we discovered (from model of table 5-3-3) that none of main effects of factors "Sex", "Year" and "City" is related to second time free of admission

Plot 5-3-1: Plot of log of survival function of residuals for model of table 5-3-3 against residuals.



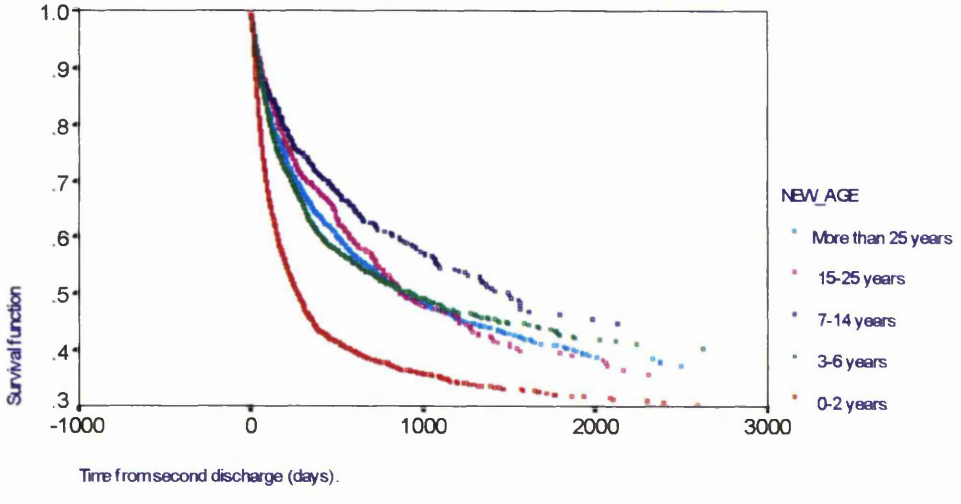
Plot 5-3-2 : LML of survival functions when new_age is as strata and all other sig. cov. are in model.



and those 2 factors interactions which were significant (i.e. Year*Age, City*Age and Sex*City) were not important. It implies there is no need to check the proportionality assumption of hazards for these factors.

Plot 5-3-3 shows the survival functions of second time free of admission in different age groups. The Kaplan-Meier method was used to estimate these survival functions ignoring the other covariates. This plot shows different survival functions cross each other. It implies any effort to model second time free of admission by using the Cox Proportional Hazards model is not valid. The reason is that, in Cox Proportional Hazards model all estimated hazard functions, corresponding to different combinations of factors, are parallel (because they are the result of multiplication of the baseline hazard function by some real numbers) therefore they can not produce some survival functions which cross each other. Note that it indicates the results which we reported previously by using model of table 5-3-3 (about differences in hazards of being admitted after second admission in different age groups) are not valid.

Plot 5-3-3 : Survival functions of second time free of admission for different age groups. Using Kaplan-Meier method.



We decided to fit separate Cox Proportional Hazard models to each age group. Tables 5-3-4 to 5-3-8 are the models which are fitted to second time free of admission. These models are respectively corresponded to age groups 1 to 5. All these models indicate that in all age groups, previous (first) time free of admission is an important factor for having longer or shorter second time free

of admission. In all age groups, the asthmatic patients who have had longer first time free of admission appear to have longer second time free of admission as well. Note in all models except the one which is corresponded to second age group (table 5-3-5) the length of stay in hospital, either previous or recent one, is another important factor. These models indicate that those patients who have longer previous or recent length of stay in hospital, would have shorter second time free of admission. Models 5-3-4 to 5-3-8 suggest also that some other factors such as "Year" and "City" may be related to second time free of admission. Note that in 3 models (models corresponding to first, third and fifth groups) the factor "City" is included in the model while factor "Year" is only included in model due to second age group. It may suggest that the differences between hazard functions in different cities (of a particular age group) is more important than the differences between hazards function in different cohort of first admission. As we discovered, the proportionality assumption of hazards for some cities and some cohort of year of admission is not valid therefore the results due to factors "City" and "Year" may not be reliable. Plots 5-3-4 to 5-3-8 show the plot of log of survival function of Cox-Snell residuals, respectively corresponding to models of tables 5-3-4 to 5-3-8 against the residuals themselves. These plots have been prepared to investigate the goodness fit of these models and all of them indicate that the models fit well.

Table 5-3-4 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2 and are in first age group.

Total No. of Cases : 2565
Prop. of Censored : 39.8%
-2 Log Likelihood (initial) : 22542.572
-2 Log Likelihood 22406.329

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	136.243	8	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-.0010	1.148E-04	79.9671	1	<.0001	.9990
CITY			21.2332	6	.0017	
CITY(2)	-.1376	.1257	1.1976	1	.2738	.8714
CITY(3)	.1059	.0896	1.3975	1	.2372	1.1117
CITY(4)	.1835	.0846	4.7009	1	.0301	1.2014
CITY(5)	.0575	.1115	.2663	1	.6058	1.0592
CITY(6)	.2503	.1066	5.5176	1	.0188	1.2844
CITY(7)	.3571	.1129	10.0054	1	.0016	1.4292
LEN_STAY	.0268	.0083	10.4454	1	.0012	1.0272

Table 5-3-5 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2 and are in second age group.

Total No. of Cases : 1592
Prop. of Censored : 51.9%
-2 Log Likelihood (initial) : 10520.896
-2 Log Likelihood 10437.023

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	83.873	9	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-8.98E-04	1.195E-04	56.5392	1	<.0001	.9991
YEAR			22.8356	8	.0036	
YEAR(2)	-.0664	.1381	.2312	1	.6306	.9357
YEAR(3)	.2030	.1283	2.5012	1	.1138	1.2250
YEAR(4)	-.1443	.1334	1.1700	1	.2794	.8657
YEAR(5)	.0057	.1326	.0018	1	.9658	1.0057
YEAR(6)	-.3792	.1539	6.0711	1	.0137	.6844
YEAR(7)	-.3503	.1451	5.8273	1	.0158	.7045
YEAR(8)	-.1359	.1703	.6371	1	.4248	.8729
YEAR(9)	-.1358	.2638	.2650	1	.6067	.8730

Table 5-3-6 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2 and are in third age group.

Total No. of Cases : 690
Prop. of Censored : 58.9%
-2 Log Likelihood (initial) : 3384.146
-2 Log Likelihood 3337.82

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	46.326	8	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-6.17E-04	1.330E-04	21.5256	1	<.0001	.9994
CITY			14.2746	6	.0267	
CITY(2)	-.5327	.2628	4.1070	1	.0427	.5870
CITY(3)	.0014	.2104	.0000	1	.9948	1.0014
CITY(4)	-.3216	.2034	2.4993	1	.1139	.7250
CITY(5)	.2074	.2413	.7388	1	.3900	1.2305
CITY(6)	-.4508	.2626	2.9483	1	.0860	.6371
CITY(7)	-.0446	.2494	.0320	1	.8580	.9564
LEN_STAY	.0587	.0221	7.0383	1	.0080	1.0605

Table 5-3-7 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2 and are in Fourth age group.

Total No. of Cases : 743
Prop. of Censored : 50.8%
-2 Log Likelihood (initial) : 4374.48
-2 Log Likelihood 4340.657

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	33.823	2	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First Time	-5.19E-04	1.184E-04	19.2472	1	<.0001	.9995
F_Len_stay	.0716	.0199	13.0014	1	.0003	1.0742

Table 5-3-8 : Cox Proportional Hazard model fitted to second time free of admission of those patients whose first admissions are type 2 and are in fifth age group.

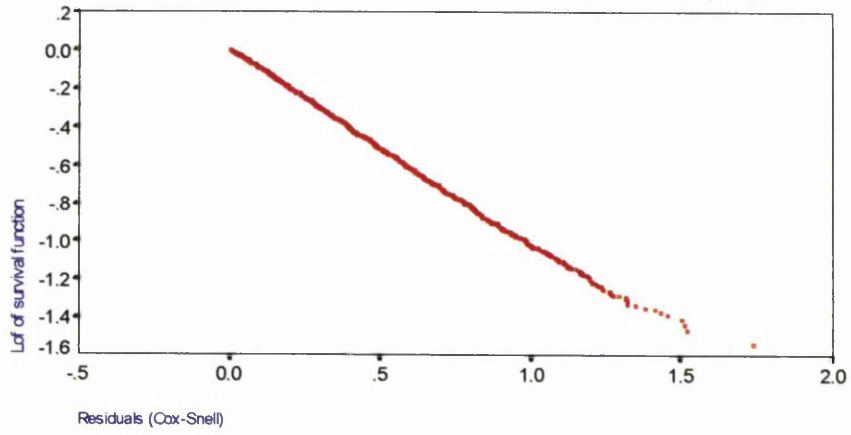
Total No. of Cases : 2555
Prop. of Censored : 51.9%
-2 Log Likelihood (initial) : 15604.296
-2 Log Likelihood : 15491.114

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	113.182	15	P<.0001

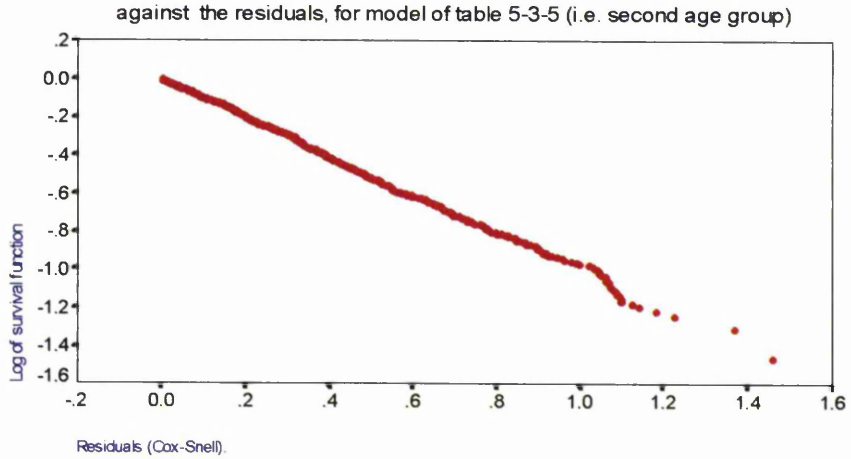
Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-5.08E-04	6.856E-05	54.8857	1	<.0001	.9995
F_Len_STAY	.0163	.0055	8.7450	1	.0031	1.0164
CITY			22.8058	6	.0009	.0263

CITY(2)	-.0785	.1425	.3038	1	.5815	.9245
CITY(3)	.0846	.1081	.6119	1	.4341	1.0883
CITY(4)	-.2543	.1130	5.0604	1	.0245	.7755
CITY(5)	-.1182	.1383	.7304	1	.3928	.8885
CITY(6)	-.0718	.1370	.2749	1	.6001	.9307
CITY(7)	-.4006	.1522	6.9252	1	.0085	.6699
SEX	.1217	.0723	2.8367	1	.0921	1.1295
SEX*CITY			19.1048	6	.0040	
SEX*CITY(2)	.0670	.2841	.0556	1	.8136	1.0693
SEX*CITY(3)	-.1928	.2156	.7996	1	.3712	.8246
SEX*CITY(4)	.4939	.2261	4.7746	1	.0289	1.6388
SEX*CITY(5)	-.1019	.2767	.1356	1	.7127	.9031
SEX*CITY(6)	.0225	.2742	.0067	1	.9347	1.0227
SEX*CITY(7)	.4862	.3044	2.5521	1	.1102	1.6262

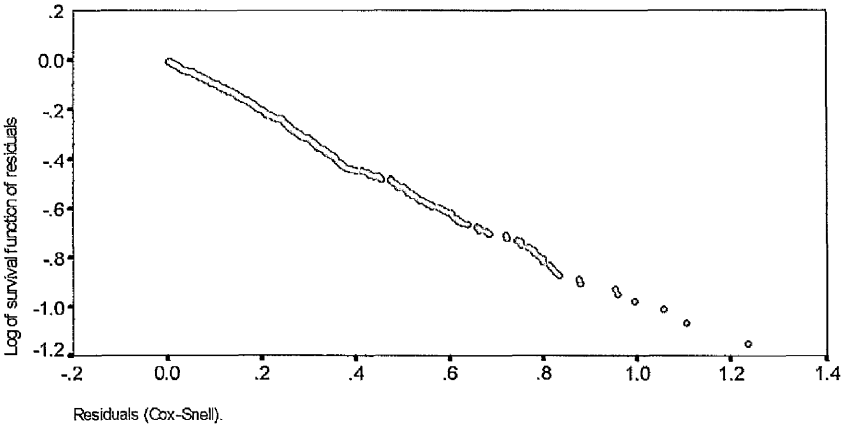
Plot 5-3-4 : Plot of log of survival function of residuals (Cox-Snell) against the residuals for model of table 5-3-4. (i.e. first age group)



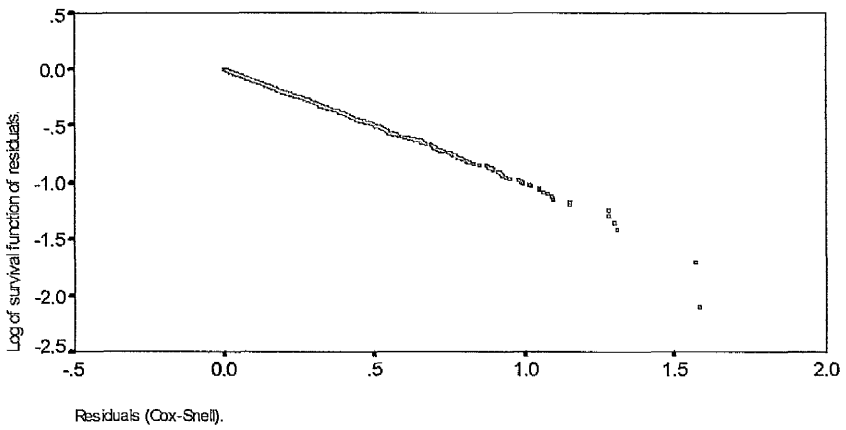
Plot 5-3-5 : Plot of log of survival function of residuals (Cox-Snell) against the residuals, for model of table 5-3-5 (i.e. second age group)



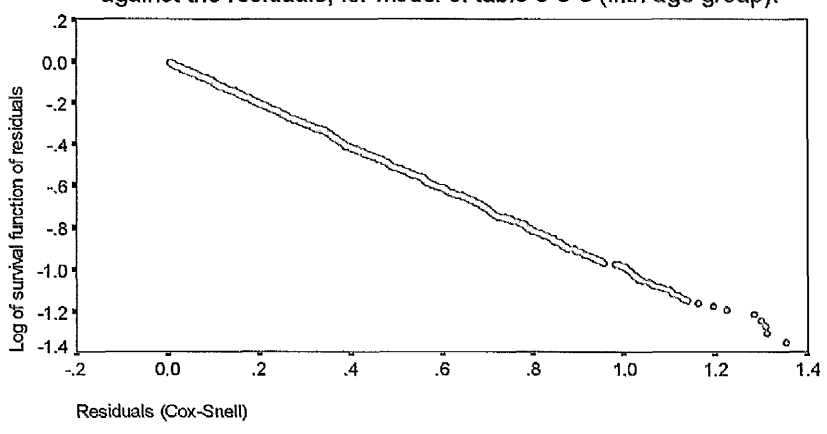
Plot 5-3-6 : Plot of log of survival function of residuals (Cox-Snell) against the residuals, for model of table 5-3-6 (i.e. third age group)



Plot 5-3-7 : Plot of log of survival function of residuals (Cox-Snell) against the residuals, for model of table 5-3-7 (i.e. fourth age group)



Plot 5-3-8: Plot of log of survival function of residuals against the residuals, for model of table 5-3-8 (fifth age group).



5-4 : Modelling Third Time Free of Admission :

In this section we intend to fit a Cox Proportional hazard model to third time free of admission. Recall that third time free of admission is defined as time interval between the third discharge from hospital and fourth admission. Third time free of admission is measured only for those patients for whom third asthma admission has already occurred i.e. the group of patients whom are going to be considered for analyses in this section are those who have returned to hospital at least twice after first admission and are at risk of being admitted for third time after first admission. There are 4046 such patients, of which the third times of 40.3% were censored.

In dealing with the third time free of admission, as with the second time free of admission, in addition to previous covariates, two new covariates should be considered. These are "second time free of admission" and "third length of stay in hospital". Tables 5-4-1 and 5-4-2 show the frequency of complete second time free of admission and third length of stay in hospital in different time intervals. Note those patients whose second times free of admission are complete are considered for studying their third time free of admission.

Table 5-4-1 : Frequency of complete second time free of admission

Second time free of admission	Frequency	Percentage
Less than a month	664	16.4
2-6 months	1599	39.5
6 months to one year	767	19.0
Between 1 and 2 years	553	13.7
Between 2 and 3 years	243	6.0
More than 3 years	36	0.9
Missing Values	184	4.5
Total	4046	

Table 5-4-2 : Frequency of third length of stay in hospital.

Length of stay in hospital	Frequency of patients	Percentage
up to one week	3618	89.4
8-14 days	327	8.1
15-21 days	64	1.6
22-28 days	19	0.5
More than 4 weeks.	16	0.4
Missing Values	2	0.0
Total	4046	

Table 5-4-3 shows the Cox Proportional Hazard model fitted to third time free of admission. The main effects of four factors first and second time free of admission and first and second length of stay in hospital as well as the main effects of previously mentioned factors and their 2 factor interactions (i.e. "Age", "Sex", "Year" and "City" and their 2 factor interactions) were candidates to enter in the model. The Stepwise Method and the likelihood ratio

test were used to select the significant covariates The model includes 8 parameters and the change in initial log likelihood is 344.801.

Model of table 5-4-3 indicates that third time free of admission of a particular patient is significantly related to his/her first and second time free of admission, his second and recent length of stay in hospital and his age group at time of first admission. Note that this model is simpler than the models which were fitted to first and second times free of admission. The order of including the covariates in the model is second time free of admission, first time free of admission, second length of stay in hospital, "Age" and finally recent length of stay in hospital.

Table 5-4-3 : Cox Proportional Hazard model fitted to third time free of admission.

Total No. of Cases : 4046
Prop. of Censored : 40.3%
-2 Log Likelihood (initial) : 36297.578
-2 Log Likelihood : 375953.777

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	344.801	8	P<.0001

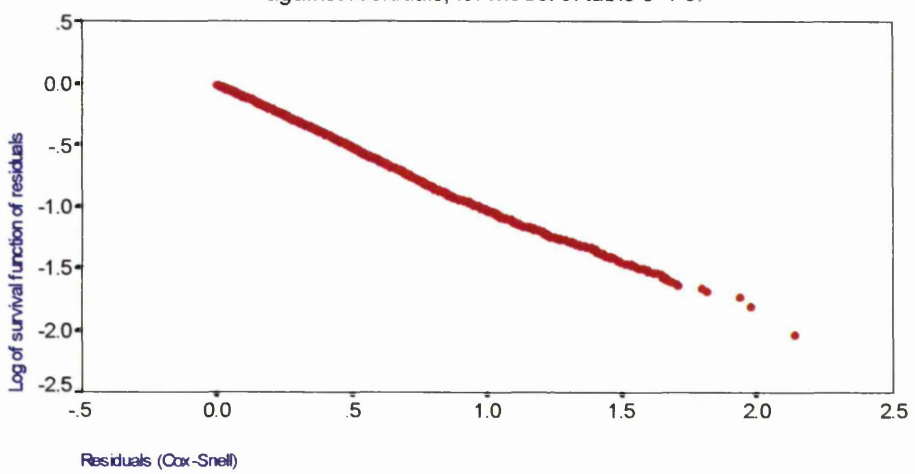
Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-4.94E-04	6.859E-05	51.8454	1	<.0001	.9995
Second_time	-8.26E-04	7.536E-05	120.0036	1	<.0001	.9992
S_Len_STAY	.0209	.0055	14.6605	1	.0001	1.0211
AGE			50.2076	4	<.0001	
AGE(2)	-.4248	.0603	49.6801	1	<.0001	.6539
AGE(3)	-.1447	.0874	2.7421	1	.0977	.8653
AGE(4)	-.0789	.0789	1.0012	1	.3170	.9241
AGE(5)	-.1195	.0580	4.2495	1	.0393	.8874
LEN_STAY	.0117	.0051	5.2182	1	.0224	1.0118

Model of table 5-4-3 suggests that patients who have longer first and second time free of admission are less at hazard of returning to hospital after third admission i.e. they have longer third time free of admission as well. The

model indicates that patients with longer second and recent length of stay in hospital have shorter third time free of admission. Hence these results are consistent with previous results from models of tables 5-3-3 and 5-2-1. The fitted model suggests that only patients in age groups 2 and 5 (at time of first admission) are significantly less than babies at risk of returning to hospital (as fourth admission). The hazard functions of third time free of admission of patients in other age groups are not significantly different from the corresponding hazards of babies, when both previous times free of admission and two lengths of stay have been taken into account.

Plot 5-4-1 shows the plot of log of survival function of Cox-Snell residuals, corresponding to model of table 5-4-3, against the residuals. The plot suggests that the model of table 5-4-3 is fitted well.

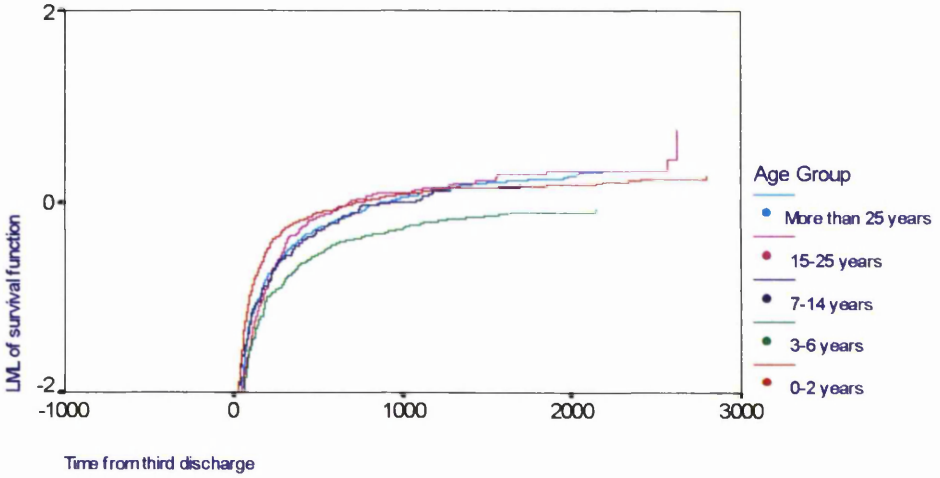
Plot 5-4-1 : Plot of log of survival function of residuals (Cox-Snell) against residuals, for model of table 5-4-3.



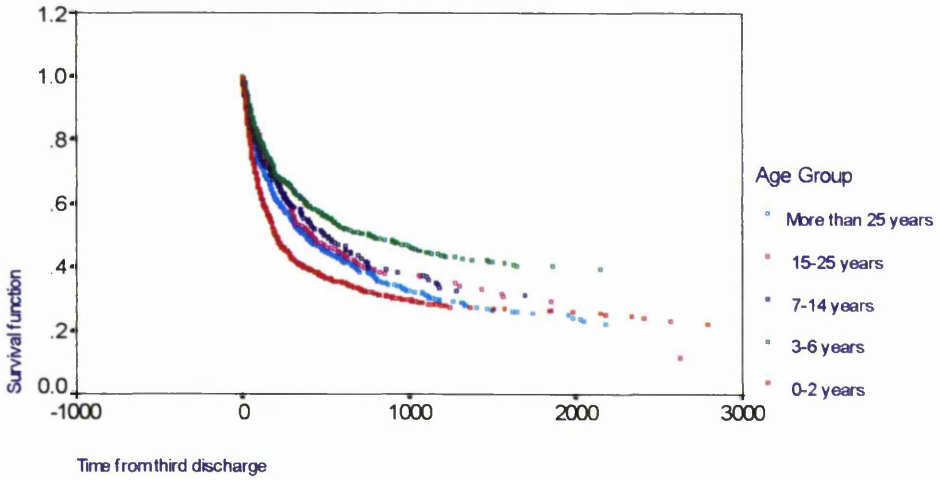
Plot 5-4-2 shows the LML plot of survival functions in different age group when the factor "Age" is as strata in model of table 5-4-3. The plot indicates that even the proportionality assumption is not valid for all age groups but for age groups 1 and 2, which are the only two age groups which their

corresponding hazards are significantly different, hazards of failure are proportional over time. Plot 5-4-3 shows the survival functions of third time free of admission in different age groups. The Kaplan-Meier method was used to estimate these survival functions.

Plot 5-4-2 : LML plot of survival functions in different age groups, when "Age" is as strata in model of table 5-4-3.



Plot 5-4-3 : Survival functions of third time free of admission in different age groups.



Tables 5-4-4 to 5-4-8 are the Cox models fitted to third time free of admission in different age groups. These tables are, respectively corresponding to age groups 1 to 5. These models suggest that, in all age groups, third time

free of admission is significantly related to two previous (i.e. first and second) times free of admission as well as to some of previous length of stay and recent length of stay in hospital. For instance, in babies age group (0-2 years old) third time free of admission is related to second length of stay and recent length of stay in hospital while in age group 2 (3-6 years) it depends to first length of stay, in age group 4 (15-25 years) it depends to none of length of stay and in fifth age group (more than 25 years) it depends to second length of stay in hospital. In babies age group, the interaction term City*Len_stay is included in the model but, considering the change in log likelihood and the value of Wald statistic, it is not important. None of other main effects or interaction terms are significantly related to third time free of admission. The convergence was not achieved for model of table 5-4-6 (corresponding to age group 3) therefore this model is totally unreliable. Plots 5-4-4 to 5-4-8 have been prepared to investigate the goodness fit of the previously mentioned models. These plots suggests that the distributions of all residuals, corresponding to different models, are E(1) i.e. all models fit well.

Table 5-4-4 : Cox Proportional Hazard model fitted to third time free of admission of those patients whose first admissions are type 2 and are in first age group.

Total No. of Cases : 1543
Prop. of Censored : 34.7%
-2 Log Likelihood (initial) : 13527.793
-2 Log Likelihood : 13388.374

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	139.419	16	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First_time	-7.51E-04	1.690E-04	19.7347	1	<.0001	.9992
Second_time	-.0010	1.585E-04	42.3797	1	<.0001	.9990
S_Len_STAY	.0243	.0110	4.8604	1	.0275	1.0246
LEN_STAY	.0301	.0224	1.8004	1	.1797	1.0306
CITY			9.6545	6	.1400	
CITY(2)	.6522	.2936	4.9362	1	.0263	1.9198

CITY(3)	.3719	.1950	3.6359	1	.0565	1.4505
CITY(4)	.3116	.1883	2.7373	1	.0980	1.3656
CITY(5)	.3292	.2517	1.7110	1	.1909	1.3898
CITY(6)	.0619	.2356	.0691	1	.7926	1.0639
CITY(7)	.5726	.2590	4.8881	1	.0270	1.7729
CITY*LEN_STAY			14.7593	6	.0222	
CITY(2)*LEN_STAY	-.2421	.0830	8.4984	1	.0036	.7850
CITY(3)*LEN_STAY	-.0228	.0606	.1411	1	.7071	.9775
CITY(4)*LEN_STAY	-.0593	.0431	1.8951	1	.1686	.9424
CITY(5)*LEN_STAY	-.0431	.0633	.4626	1	.4964	.9579
CITY(6)*LEN_STAY	.0480	.0589	.6648	1	.4149	1.0492
CITY(7)*LEN_STAY	-.1823	.0985	3.4292	1	.0641	.8333

Table 5-4-5 : Cox Proportional Hazard model fitted to third time free of admission of those patients whose first admissions are type 2 and are in second age group.

Total No. of Cases : 769
Prop. of Censored : 49.9%
-2 Log Likelihood (initial) : 4792.2
-2 Log Likelihood : 4747.931

Chi-Square	df	Sig
Change (-2LL) from Previous Block	44.269	3 P<.0001

Variable	**B**	**S.E.**	**Wald**	**df**	**Sig**	**Exp(B)**
First time	-6.92E-04	1.912E-04	13.0845	1	.0003	.9993
Second time	-7.96E-04	1.786E-04	19.8592	1	<.0001	.9992
F_Len_STAY	.0844	.0325	6.7279	1	.0095	1.0881

Table 5-4-6 : Cox Proportional Hazard model fitted to third time free of admission of those patients whose first admissions are type 2 and are in third age group.
*Convergence was not achieved for this model.

Total No. of Cases : 283
Prop. of Censored : 45%
-2 Log Likelihood (initial) : 1572.979
-2 Log Likelihood : 1461.996

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	110.983	69	.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Second_time	-8.96E-04	2.794E-04	10.2736	1	.0013	.9991
LEN_STAY	.2214	6.2854	.0012	1	.9719	1.2478
YEAR			3.3802	8	.9083	
YEAR(2)	-.8852	.7076	1.5651	1	.2109	.4126
YEAR(3)	.3705	.6092	.3700	1	.5430	1.4485
YEAR(4)	-.3444	2.3230	.0220	1	.8821	.7086
YEAR(5)	.0308	.5529	.0031	1	.9556	1.0313
YEAR(6)	-1.0400	2.4177	.1850	1	.6671	.3535
YEAR(7)	-1.4034	4.4728	.0985	1	.7537	.2458
YEAR(8)	-1.1095	1.7336	.4096	1	.5222	.3297
YEAR(9)	-5.7680	146.2099	.0016	1	.9685	.0031
CITY			.6232	6	.9960	
CITY(2)	.0580	3.4058	.0003	1	.9864	1.0597
CITY(3)	.3992	4.5337	.0078	1	.9298	1.4907
CITY(4)	-.0788	32.6633	.0000	1	.9981	.9242
CITY(5)	.5553	3.0420	.0333	1	.8552	1.7424
CITY(6)	-1.2641	37.6904	.0011	1	.9732	.2825
CITY(7)	-.4971	3.3744	.0217	1	.8829	.6083
YEAR*CITY			50.0783	45*	.2789	
YEAR(2)*CITY(2)	-3.2960	1.3266	6.1731	1	.0130	.0370
YEAR(3)*CITY(2)	1.2865	1.3271	.9397	1	.3324	3.6200
YEAR(4)*CITY(2)	-1.4092	1.2035	1.3711	1	.2416	.2443
YEAR(5)*CITY(2)	-.6882	1.3428	.2627	1	.6083	.5025
YEAR(6)*CITY(2)	-5.6962	13.6919	.1731	1	.6774	.0034
YEAR(7)*CITY(2)	2.0897	27.2851	.0059	1	.9390	8.0825
YEAR(8)*CITY(2)	-.4207	1.4441	.0849	1	.7708	.6566
YEAR(2)*CITY(3)	-2.7491	1.2284	5.0087	1	.0252	.0640
YEAR(3)*CITY(3)	-1.0508	1.3591	.5978	1	.4394	.3497
YEAR(4)*CITY(3)	-.8011	.8619	.8639	1	.3527	.4489
YEAR(5)*CITY(3)	-.7761	1.2436	.3895	1	.5326	.4602
YEAR(6)*CITY(3)	-2.1910	1.2922	2.8748	1	.0900	.1118
YEAR(7)*CITY(3)	3.1215	27.2149	.0132	1	.9087	22.6806
YEAR(8)*CITY(3)	-6.2534	6.1784	1.0244	1	.3115	.0019
YEAR(9)*CITY(3)	7.8796	29.6685	.0705	1	.7906	2642.7230
YEAR(2)*CITY(4)	-1.5472	.8029	3.7134	1	.0540	.2128
YEAR(3)*CITY(4)	-.0685	1.2293	.0031	1	.9556	.9338
YEAR(4)*CITY(4)	-3.0902	1.0136	9.2943	1	.0023	.0455
YEAR(5)*CITY(4)	-.6236	1.3037	.2288	1	.6324	.5360
YEAR(6)*CITY(4)	-.9875	1.1725	.7094	1	.3997	.3725
YEAR(7)*CITY(4)	3.5192	27.2128	.0167	1	.8971	33.7584
YEAR(8)*CITY(4)	-.4240	1.5334	.0764	1	.7822	.6545
YEAR(9)*CITY(4)	-5.1358	292.6955	.0003	1	.9860	.0059
YEAR(2)*CITY(5)	-3.7471	1.2961	8.3587	1	.0038	.0236
YEAR(3)*CITY(5)	-.6072	1.4586	.1733	1	.6772	.5449
YEAR(4)*CITY(5)	-2.0495	.9826	4.3507	1	.0370	.1288
YEAR(5)*CITY(5)	-.6256	1.3677	.2093	1	.6474	.5349
YEAR(6)*CITY(5)	-1.2541	1.1127	1.2703	1	.2597	.2853
YEAR(7)*CITY(5)	5.7318	27.2270	.0443	1	.8333	308.5104
YEAR(8)*CITY(5)	-2.1335	1.4092	2.2922	1	.1300	.1184
YEAR(2)*CITY(6)	-.7487	1.1246	.4432	1	.5056	.4730
YEAR(3)*CITY(6)	.6309	1.4991	.1771	1	.6739	1.8793

YEAR(4)*CITY(6)	-5.1490	15.7817	.1064	1	.7442	.0058
YEAR(5)*CITY(6)	-1.5482	1.6669	.8626	1	.3530	.2126
YEAR(6)*CITY(6)	.2992	1.1762	.0647	1	.7992	1.3488
YEAR(7)*CITY(6)	-.6574	30.8880	.0005	1	.9830	.5182
YEAR(8)*CITY(6)	.1430	1.6649	.0074	1	.9315	1.1537
YEAR(9)*CITY(6)	-4.0279	337.4257	.0001	1	.9905	.0178
YEAR(2)*CITY(7)	-3.2472	1.4548	4.9818	1	.0256	.0389
YEAR(3)*CITY(7)	.1703	1.5006	.0129	1	.9096	1.1857
YEAR(4)*CITY(7)	-1.2440	1.1397	1.1915	1	.2750	.2882
YEAR(5)*CITY(7)	1.7878	1.6772	1.1362	1	.2865	5.9760
YEAR(6)*CITY(7)	-5.2384	9.1854	.3252	1	.5685	.0053
YEAR(7)*CITY(7)	4.8544	27.2201	.0318	1	.8585	128.310
YEAR(8)*CITY(7)	-6.2268	9.5372	.4263	1	.5138	.0020
YEAR*LEN_STAY			7.3761	8	.4967	
YEAR(2)*LEN_STAY	-.0167	.1309	.0163	1	.8984	.9834
YEAR(3)*LEN_STAY	-.1522	.1287	1.3978	1	.2371	.8589
YEAR(4)*LEN_STAY	-.0356	.1396	.0649	1	.7989	.9650
YEAR(5)*LEN_STAY	-.0832	.1172	.5033	1	.4780	.9202
YEAR(6)*LEN_STAY	-.2151	.1400	2.3600	1	.1245	.8065
YEAR(7)*LEN_STAY	.1709	.1722	.9848	1	.3210	1.1863
YEAR(8)*LEN_STAY	.1869	.2129	.7711	1	.3799	1.2055
YEAR(9)*LEN_STAY	.5956	56.5676	.0001	1	.9916	1.8142

* Df reduced because of constant or linearly dependent covariates.

Table 5-4-7 : Cox Proportional Hazard model fitted to third time free of admission of those patients whose first admissions are type 2 and are in fourth age group.

Total No. of Cases : 362
Prop. of Censored : 43%
-2 Log Likelihood (initial) : 2136.202
-2 Log Likelihood : 2088.646

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	47.556	2	P<.0001

Variable	**B**	**S.E.**	**Wald**	**df**	**Sig**	**Exp(B)**
First time	-5.36E-04	1.891E-04	8.0338	1	.0046	.9995
Second time	-.0013	2.341E-04	31.8397	1	<.0001	.9987

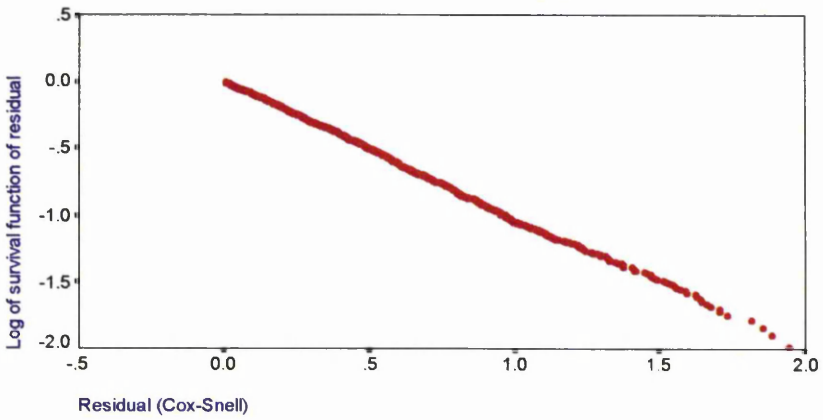
Table 5-4-8 : Cox Proportional Hazard model fitted to third time free of admission of those patients whose first admissions are type 2 and are in fifth age group.

Total No. of Cases : 1089
Prop. of Censored : 38.4%
-2 Log Likelihood (initial) : 7607.969
-2 Log Likelihood : 7549.961

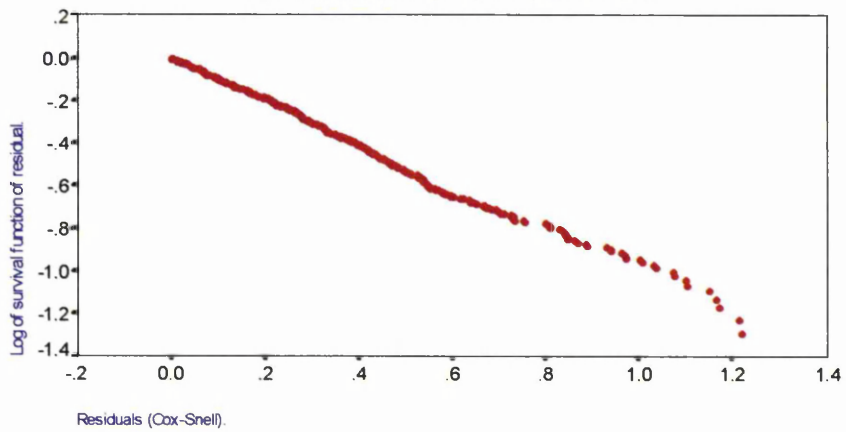
	Chi-Square	df	Sig
Change (-2LL) from Previous Block	58.008	3	P<.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First time	-3.44E-04	1.006E-04	11.6684	1	.0006	.9997
Second time	-6.05E-04	1.239E-04	23.8045	1	<.0001	.9994
S_L_STAY	.0261	.0063	17.3165	1	<.0001	1.0265

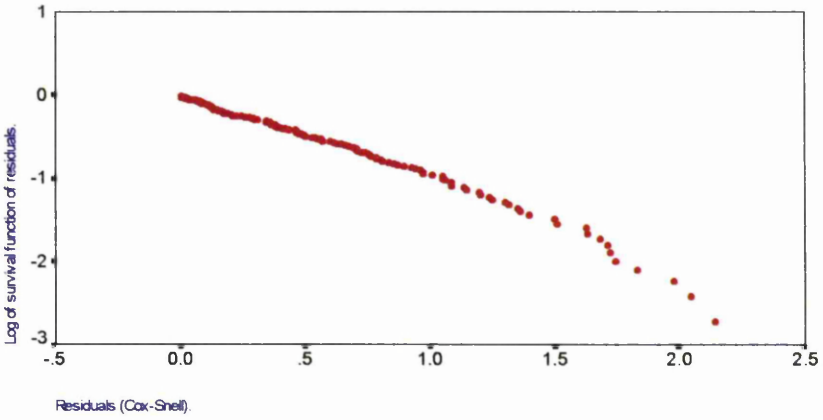
Plot 5-4-4: Plot of log of survival function of residuals against the residuals. For model of table 5-4-4.



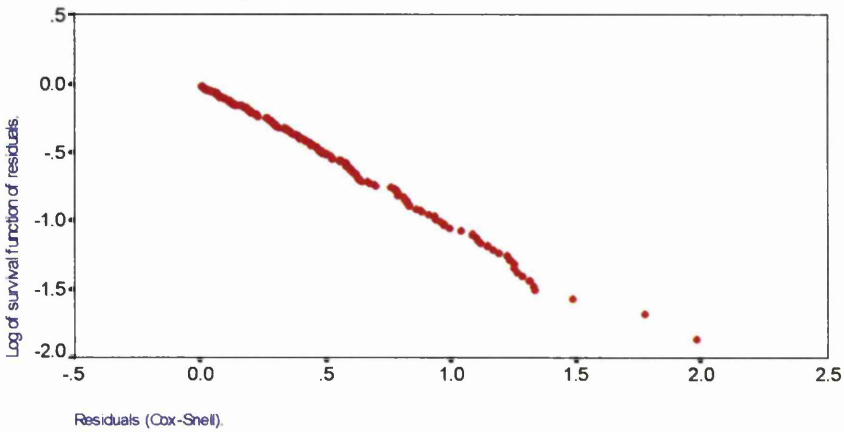
Plot 5-4-5 : Plot log of survival function of residuals (Cox-Snell) against residuas. For model of table 5-4-5.



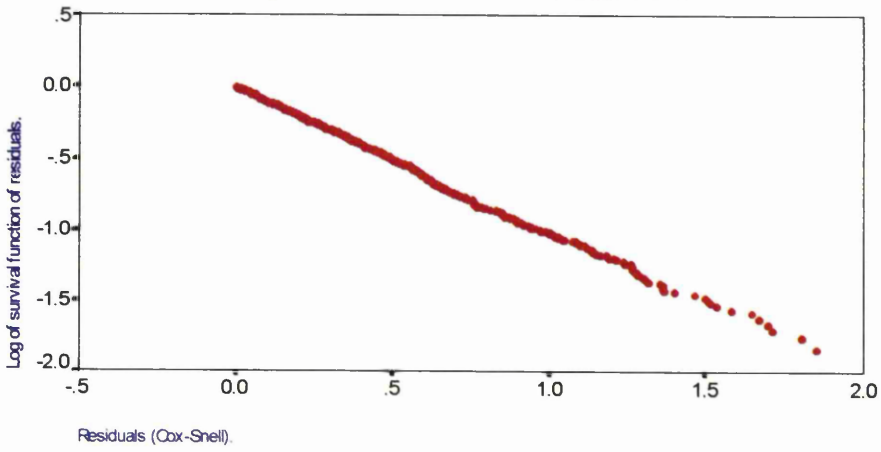
Plot 5-4-6 : Plot of log of survival function of residuas against the residuals. For model of table 5-4-6.



Plot 5-4-7 : Plot of log of survival functiuon of residuals (Cox-Snell) against the residuals. For model of table 5-4-7.



Plot 5-4-8 : Plot of log of survival function of residuals (Cox-Snell) against residuals. For model of table 5-4-8.



5-5 : Summary :

After a review of Cox Proportional Hazards Models for survival data, such models have been fitted successively to first, second and third times free of admission.

The more important covariates are as follows :

First time : Age, Length of stay, Sex, Age*Sex.

Second time : First time, Age, Length of stay.

Third time : Second time, First time, Length of stay, Age.

As a patient progress from first to second and then to a third time free of admission, covariates describing his individual history (previous time(s) free of admission, length of stay) become available. Merely demographic variables (Age, Sex, ...) therefore become less important.

The decreasing importance of Age is illustrated in plots 5-2-3, 5-3-2 and 5-4-2 (respectively first, second and third times free of admission).

Chapter 6

Analysis of Times Free of Admission

In this chapter we intend to carry out some simple tests and comparisons to discover the distribution of times free of admission of a particular asthmatic patient as well as the relation between each time free of admission and its previous times.

We remind the reader that some times free of admission (the last time of each patient) are censored or incomplete. Note these times can not be treated in a similar way as complete times. Since the methods which we are going to use in some sections of this chapter are particularly designed for complete times, therefore in this chapter, we sometimes consider only the complete or uncensored times free of admission. In principle this may introduce bias.

6-1 : Distribution of times free of admission of a particular patient :

In this section we intend to discover the distribution of times free of admission of a particular patient. Here the complete times of each patient are considered. Note that for each patient we need large enough number of admissions (i.e. large enough number of times free of admission) to estimate the parameter(s) of any assumed distribution properly. We simply decided to select those asthmatic patients who had at least 15 complete times free of

admissions (i.e. 15 admissions after their first admission to hospital) during their observed time. Note each of these patients has 15 complete times free of admission therefore all tests and estimated parameter(s) are relatively reliable. Also, the bias due to ignoring the patient's single incomplete time should be small. We also decided to restrict our consideration to those patients whose year of first admission was type 2 and was happened in year 1984. It fixes the period of observation for all selected patients (in average 8.5 years for each patient) therefore any changes in number of admissions (and in times free of admission) can't be simply due to different observed times. There were 24 such patients. It was difficult (but not impossible) to investigate the distribution of times of all these patients. Since we were interested in investigating the goodness of fit of different distributions we decided to draw a sample of 6 of these patients and to fit different distributions to the times of each patient. Systematic Sampling was used to choose the sample patients, sorting these according to their number of admissions and then choosing numbers 2, 6, 10, 14, 18 and 22 (number 2 was derived by Simple Random Sampling form numbers 1 to 4). Some characteristics of these patients are presented later.

Before going through the rest of this chapter, it should be mentioned that we are aware that these 6 patients are not typical. They just are chosen to have many admissions. In general most of patients have too few number of later admissions to be able to fit a distribution to their times free of admission. We also are aware that in section 2-7 we have shown that in certain age groups the intensity of admission decreased as time passed.

It was decided to test goodness of fit of four distributions to times free of admission of each patient. These distributions are Exponential, Gamma, Weibull and Log Normal. Note that the Exponential distribution is a special case of Gamma and Weibull. Therefore when the exponential distribution fits

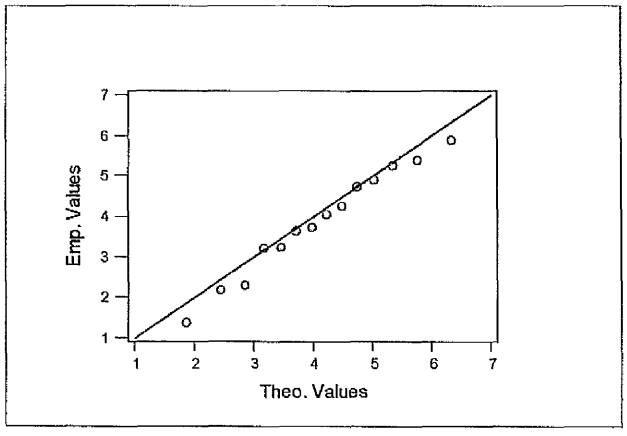
well, both the Gamma and Weibull distribution also fit well. In such cases we assumed the distribution of times free of admission to be Exponential. No formal test was carried out. We only used Q-Q plots and P-P plots to judge whether times free of admission of any patient have a particular distribution or not. Recall that Q-Q plot is the plot of theoretical values for times free of admission against empirical or observed times free of admission and P-P plot shows the plot of theoretical probabilities against the empirical probability. If the result of a Q-Q plot or a P-P plot is a straight line through the origin then we conclude that the assumed distribution fits well. Larger deviance from the straight line means a larger difference between the theoretical and empirical distribution. Note that the judgement for linearity or non linearity of Q-Q plot and P-P plot is not numerical i.e. just by looking at the plot we conclude the results.

Table 6-1-1 shows some important characteristics of selected patients as well as their number of admissions after first admission and the mean and standard deviation of their times. For each patient, the Q-Q and P-P plots, corresponding to the distribution which fits best, are presented.

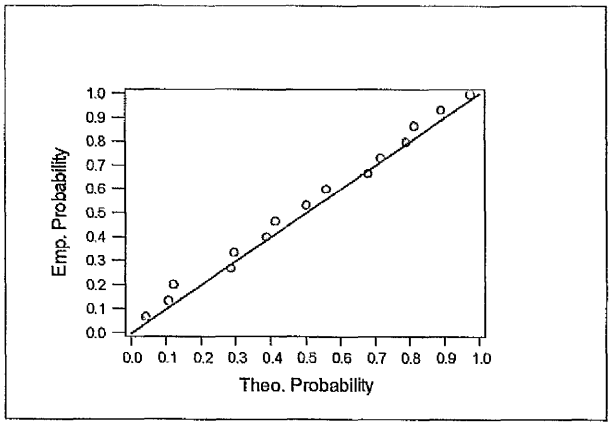
Table 6-1-1 : Some characteristics of the selected patients and the fitted distributions.

Patient No.	Age	Sex	City of first ad.	No. of ad.'s after first ad.	Mean	S.D.	Fitted Distribution
1	21	Male	Glasgow	15	153.9	252.3	Log Normal
2	33	Female	Edinburgh	16	114.0	157.7	Log Normal
3	2	Female	Glasgow	18	147.0	249.8	None
4	1	Male	Glasgow	20	140.3	119.7	Weibull
5	1	Female	Selkirk	30	38.1	39.9	Exponential
6	2	Male	Paisley	50	60.5	60.2	Exponential

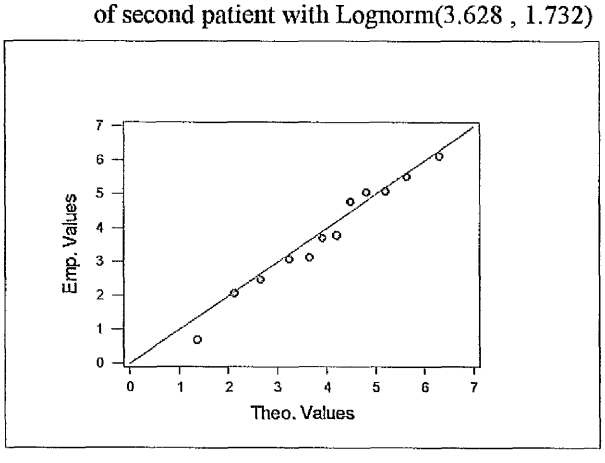
Plot 6-1-1 : Q-Q plot for comparing the times free of admission of first patient with Lognorm(4.087 , 1.495)



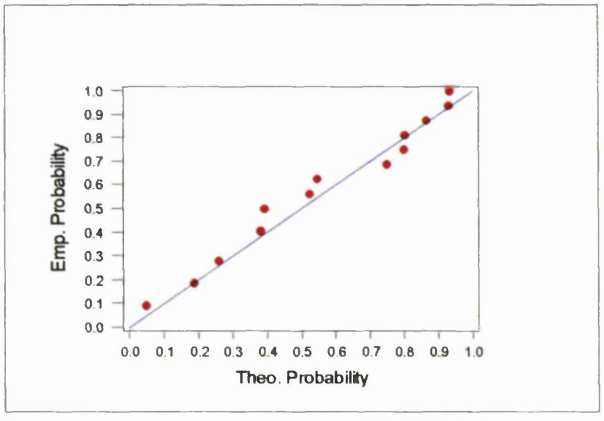
Plot 6-1-2 : P-P plot for comparing the times free of admission of first patient with Lognorm(4.087 , 1.495)



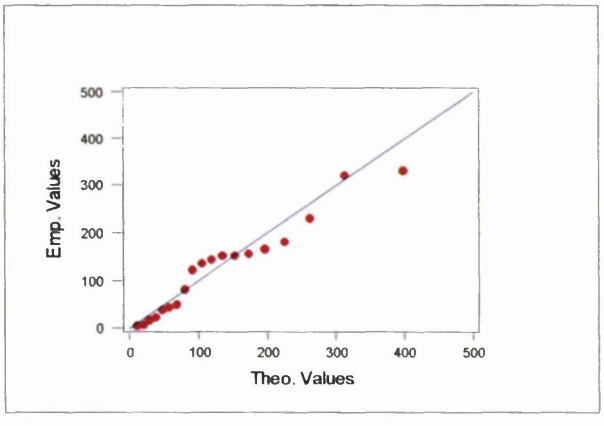
Plot 6-1-3 : Q-Q plot for comparing the times free of admission of second patient with Lognorm(3.628 , 1.732)



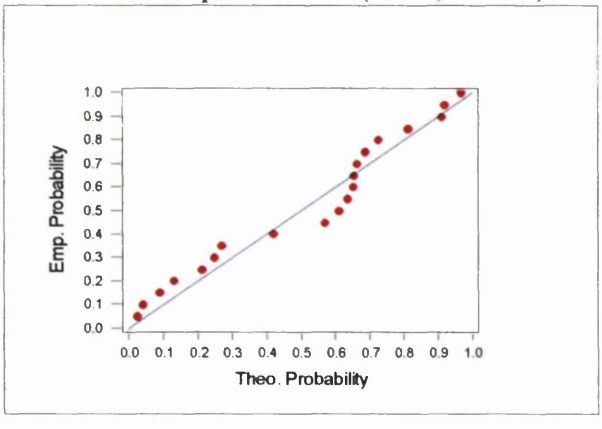
Plot 6-1-4 : P-P plot for comparing the times free of admission of second patient with Lognorm(3.628 , 1.732)



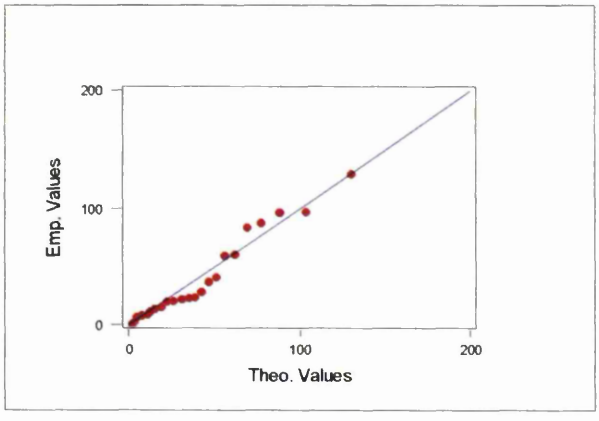
Plot 6-1-5 : Q-Q plot for comparing the times free of admission of fourth patient with W(1.083 , 144.493)



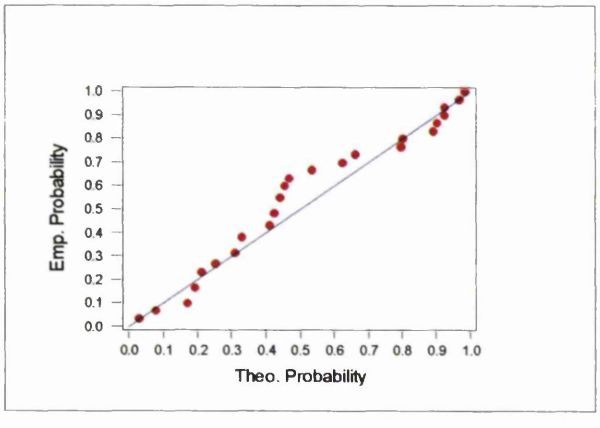
Plot 6-1-6 : P-P plot for comparing the times free of admission of fourth patient with W(1.083 , 144.493)



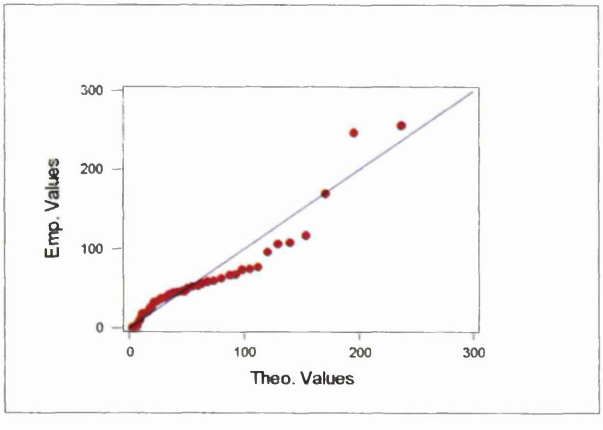
Plot 6-1-7 : Q-Q plot for comparing the times free of admission of fifth patient with E(38.1)



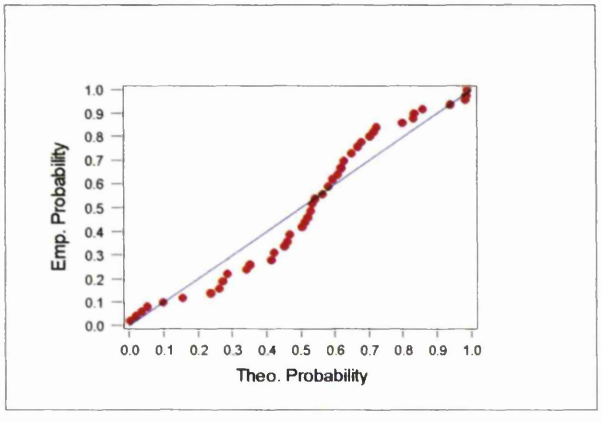
Plot 6-1-8 : P-P plot for comparing the times free of admission of fifth patient with E(38.1)



Plot 6-1-9 : Q-Q plot for comparing the times free of admission of sixth patient with E(60.5)



Plot 6-1-10 : P-P plot for comparing the times free of admission of sixth patient with E(60.5)



6-2 : Relation between each time free of admission and its previous times :

In this section we intend to discover the relation between each time free of admission and its previous times. We considered only those patients whose first admission was type 2 and their year of first admission was year 1984. Note that, as an example, when we are interested to investigate the relation between third time free of admission and the previous times (i.e. the second and the first time free of admission) we are able to investigate this only for those patients who have at least 2 admissions after their first admission.

We decided to use survival models to investigate the relation between each time free of admission and its previous times. For survival models give the opportunity to consider censored responses as well. The use of survival models avoids this criticism by considering only the complete times. In particular, the Cox Proportional Hazard Model was used to construct the model between each time free of admission (either complete or censored) and its previous (complete) times. In all models the Stepwise Method was used to enter the previous times in the model.

Tables 6-2-1 to 6-2-6 show the Cox Proportional Hazard models between, respectively, second to seventh time free of admission and their previous times free of admission. For each model, the total number of patients as well as the number of patients who were available for analysis are mentioned. These models suggest that while the third time free of admission is significantly related to both second and first times free of admission (i.e. to two previous times), the fourth, fifth and sixth times free of admission are only

related to the previous time free of admission. Model 6-2-6 indicates that the seventh time free of admission is, once again, related to two most recent previous times free of admission (i.e. to sixth and fifth times).

We checked also the relation of other times free of admission with their previous times but no consistent result was obtained. For example we found that the eighth time free of admissions depends on none of previous times, ninth time free of admission depends on eighth and seventh times and tenth time free of admission depends to ninth and seventh times. These models are not presented here. Note that the inconsistency among the recent results could be related to small number of patients which was available for analysis.

It is difficult to come to any absolute conclusion about the relation between each time free of admission and its previous times. But, as far as we considered, it is clear that each time free of admission depends at most on two of its previous times. These are usually the two most recent previous times. In many cases, a particular time free of admission is related only to its most recent previous time. In all models 6-2-1 to 6-2-6 $\hat{\beta} < 0$ indicating, longer previous "explanatory" time results in lower hazard i.e. longer "response" time. So presumably, a patient's successive times are positively correlated. This may be simply because a patient with a long second (and/or first) time is, other things being equal, not so ill as the other patients with at least 2 complete times. So this patient is expected to have a long third time also.

Table 6-2-1 : Cox Proportional Hazard model between second and first time free of admission. For those patients who had at least 1 admission after first admission.

```
No. of total cases : 1315
No. Of valid cases : 1305
No. of censored    : 577 (44.2%)
-2 Log Likelihood (initial) : 9801.552
-2 Log Likelihood           : 9736.804
```

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	64.748	1	.0000

Variable	B	S.E.	Wald	df	Sig	Exp(B)
First time	-4.98E-04	6.740E-05	54.5047	1	.0000	.9995

Table 6-2-2 : Cox Proportional Hazard model between third and all previous times free of admission. For those patients who had at least 2 admissions after first admission.

No. of total cases : 732
No. Of valid cases : 729
No. of censored : 282 (38.7%)
-2 Log Likelihood (initial) : 5437.083
-2 Log Likelihood : 5382.989

	Chi-Square	df	Sig
Change (-2LL) from Previous Step	8.734	1	.0031

Variable	B	S.E	Wald	df	Sig	Exp(B)
First time	-2.86E-04	1.016E-04	7.9308	1	.0049	.9997
Second time	-7.89E-04	1.307E-04	36.4342	1	.0000	.9992

Table 6-2-3 : Cox Proportional Hazard model between fourth time and all previous times free of admission. For those patients who had at least 3 admissions after first admission.

No. of total cases : 447
No. Of valid cases : 442
No. of censored : 135 (30.5%)
-2 Log Likelihood (initial) : 3364.332
-2 Log Likelihood : 3348.837

	Chi-Square	df	Sig
Change (-2LL) from Previous Step	15.495	1	.0001

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Third time	-5.91E-04	1.639E-04	12.9816	1	.0003	.9994

Table 6-2-4 : Cox Proportional Hazard model between fifth time and all previous times free of admission. For those patients who had at least 4 admissions after first admission.

No. of total cases : 308
No. Of valid cases : 305
No. of censored : 86 (28.2%)
-2 Log Likelihood (initial) : 2248.303
-2 Log Likelihood : 2229.5

	Chi-Square	df	Sig
Change (-2LL) from Previous Step	18.802	1	.0000

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Fourth time	-7.91E-04	2.069E-04	14.6202	1	.0001	.9992

Table 6-2-5 : Cox Proportional Hazard model between sixth time and all previous times free of admission. For those patients who had at least 5 admissions after first admission.

No. of total cases : 219
No. Of valid cases : 219
No. of censored : 63 (28.8%)
-2 Log Likelihood (initial) : 1494.845
-2 Log Likelihood : 1486.129

	Chi-Square	df	Sig
Change (-2LL) from Previous Step	8.717	1	.0032

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Fifth time	-9.15E-04	3.499E-04	6.8416	1	.0089	.9991

Table 6-2-6 : Cox Proportional Hazard model between seventh time and all previous times free of admission. For those patients who had at least 6 admissions after first admission.

No. of total cases : 165
No. Of valid cases : 153
No. of censored : 38(24.8%)
-2 Log Likelihood (initial) : 998.707
-2 Log Likelihood : 974.72

	Chi-Square	df	Sig
Change (-2LL) from Previous Block	23.987	2	.0000

Variable	B	S.E.	Wald	df	Sig	Exp(B)
Fifth time	-.0012	5.537E-04	5.0388	1	.0248	.9988
Sixth time	-.0014	3.993E-04	12.0246	1	.0005	.9986

6-3 : Summary :

In 6-1 the distributions of times free of admission of 6 asthmatic patients were investigated. Since the last time of each patient was censored we ignored it. We couldn't find any common distribution for times free of admission of all 6 patients (see table 6-1-1).

In 6-2 we showed that a patient's time free of admission was related at most to his/her two recent previous times.

Chapter 7

Further Analyses, Multilevel Model Approach in Analysis of Asthma Admissions and Methodological Issues

So far in chapters 3 to 6 we have tried different approaches to analyse the pattern of either first or later asthma admissions and its relation with some factors. In these chapters sometimes we came to some new results which demanded further analyses to answer some new questions or sometimes we restricted ourselves to consider some of the factors (not all of factors) or a part of the data for a particular patient. Note that otherwise we could not carry out the analyses. As some examples of these restrictions, we decided to ignore the factor season in analysing the pattern of first asthma admissions or we considered only the values of factors at time of first admission to investigate the effect of the factors on the pattern of later admissions. Note we were aware of the fact that there is a seasonal pattern in first asthma admissions and that a patient who at time of his/her first admission is a baby is likely not to be any longer a baby at time of his/her second admission which, for example, may happen 3 years later

In this chapter we suggest some further analyses which can answer some further questions, and can also increase the reliability of the analyses. As we

have made a substantial effort to use the Multilevel Model and in particular the Multilevel Survival Model, we allocate a separate section to describe these types of models and their probable advantages in application to our data. At end of this chapter we discuss a number of methodological issues.

7-1 : Further Possible Analyses:

These further possibilities will be mentioned in section 7-2-2, where we will introduce the Multilevel model and its applications in analysing the pattern of asthma admissions. Here we only suggest those further analyses which are not related to Multilevel models.

Through chapters 2 to 6 we considered the relation between different response variables and different factors. In chapter 3 the 'Number of first admissions' was as response variable (Log Linear models) while in chapter 4 the mean of later admissions as well as the proportion of returning to hospital was considered as the response variables (Weighted Regression and Logistic models). In chapter 5 we studied different times (i.e. first, second and third) free of admission. In none of these chapters was it practically possible to include all factors into the model. We ignored some factors because there were too few patients at some levels (such as 'Discharge Code' or 'Admitted From'). Some others also were not considered because the number of cases in different combinations of factors became too small (i.e. many cells with small counts). One of the most important of these recent factors (which have been considered) is the factor 'Season'. Note we have discussed the relation between this factor and first admissions (and very briefly with later admissions) in chapter 2. One can consider the relation between the factor season and both first admissions and later admissions by using formal models. Through the use of these results

others may be able to ignore some of the factors which we have already used in our models and so make it possible to enter 'season' in the models.

In all analyses we have studied the effect of factors which were measured at time of patients' first admission. Note that since the patients were followed up for a relatively long time the values of some factors may change from one admission to the next and so modify the relation which we are looking for. In chapter 4 the type of models used did not allow the possibility of considering any changes in the values of factors at later admissions. In chapter 5, for consistency, we followed the same policy (i.e. we considered the values of factors at time of first admission as explanatory variables for different times free of admission). One can change this policy, and at least in chapter 5, consider the values of factors at time of, for example first, second and third admission to study their relation with these times free of admission.

During our visit with some managers in Greater Glasgow Health Board we understood that they are very interested to compare the pattern of asthma admissions in rural and urban areas. Given a clear definition of rural and urban area, one can use the postcode sector, which we used to create the factor 'City', to group the asthmatic patients into rural and urban areas and compare their patterns.

In chapter 5, it was possible to consider the previous time free of admission as a time dependent covariate. In addition, other types of survival models, namely accelerated life models or log duration models, can be considered. In chapter 5, the proportionality assumption of hazards was sometimes not valid for some models therefore these new suggested survival models could be used and the results compared.

In chapter 6 we have examined the distributions which can be fitted to times free of admission of a sample of 6 patients. We believe these patients are

not typical and the results can't be generalised to all asthmatic patients. The reason is that in 2-7 we showed the intensity function of returning to hospital, even after next admissions, depends on time from first discharge. Therefore no distribution could be assumed for repeated times free of admission of a particular asthmatic patients. Note that as the results of 2-7 are probably not correct for the patients who are in our sample a distribution may be fitted to their times. However, the results can not be generalised. We think further analyses are needed to understand the distribution of times free of admission.

In connection with chapter 6 we also tried to use the complete times to discover the distribution of first, second and third times free of admission. Later we understood that the bias corresponding to ignoring the censored times is substantial and therefore any fitted distribution, which has not considered the censored times, is unreliable. We did not include this part in the thesis because we realised that further analyses are needed to discover the correct shape of the distribution. We were unfortunately out of time to do this. Note in such a situation the survival methods should be used to find the information about the distribution of first, second or third times free of admission. By studying the survival functions or the hazard functions, probably been prepared for different age groups, and considering $F(t)=1-S(t)$ (where $S(t)$ and $F(t)$ are, respectively, the survival and the distribution functions), one may discover the correct distribution of first, second and third times free of admission.

7-2 : Multilevel Models :

Many systems for which data is collected (such as schools, hospitals, cities and individuals) have a hierarchical organisation in which 'units' at one level are grouped within units at the next level. For example different measurements of an individual are nested in the individual and this individual is nested in schools or hospitals which in turn are also nested in cities. The type of models which deal with data with this hierarchical structure is known as Multilevel Models. As many different types of data have a hierarchical structure the use of Multilevel Models is very wide (Cronbach and Webb 1975, Goldstein 1987, 1995).

7-2-1 : Basic Multilevel Model :

Multilevel Model is one extension of ordinary multiple regression. As an example, suppose 5000 pupils drawn from 100 schools (a 2-level model); thus the groups here are the schools. Suppose we wish to investigate the relationship between two measurements Y_i and X_i (for pupil i). Ordinary regression would estimate a single equation by pooling all 5000 cases :

$$Y_i=\beta_0+\beta_1 X_i+e_i \qquad (1)$$

where β_0 is the intercept and β_1 is the slope coefficient and both are parameters to be estimated. The term e_i is a random variable, often called an error and usually assumed to be normally distributed with mean 0 and a constant variance.

The difficulty with (1) is that it does not allow for school differences i.e. the effect of the school which the pupil have attended is ignored.

A multilevel model provides the appropriate generalisation of (1) to take into account the school differences. A multilevel version of (1) can be written as :

$$Y_{ij}=\beta_0+\beta_1 X_{ij}+u_j+e_{ij} \qquad (2)$$

where X_{ij} and Y_{ij} are, respectively, the independent and the response variable corresponding to i-th pupil in j-th school, and term u_j is the j-th school contribution to response of pupils who have attended in that school. u_j is a random variable, assumed to have a zero mean and a constant variance. It is possible to enter some covariates related to schools in (2) (level-2 covariate) or to consider some coefficients as random.

Note that it would, in principal, be possible to estimate values of u_j using the standard extension of (1) known as analysis of covariance. In practice, however, this would be cumbersome, and not feasible at all if the number of schools was very large. Moreover, we would typically be interested in making inferences about the variation between all schools not merely the schools which have been sampled. The key technical advance of multilevel modelling is to assume the u_j vary randomly across the schools. Note that in a hierarchical structure, the units which are nested in a particular upper level are allowed to be dependent while units in different upper levels are independent.

A particularly interesting application of Multilevel Models is to repeated measurements on individual, where the lowest level units (level 1) are 'occasions' and the higher level units (level 2) are individual subjects. Simple versions of these techniques have been used for many years in agriculture, genetics and medicine, often under the name of variance components.

A common approach to analysing hierarchical data has been to aggregate to the group level and then use only group means. Thus instead of using information about the 5000 pupils in the above example, only the 100 school

means would be used. Ordinary regression would be used to relate the mean of responses and the mean of independent variables in different schools. There is a technical problem with this approach and that is the statistical estimates can be very unreliable in the sense that slight perturbations to the data or to the model can produce markedly different results.

One difficulty with Multilevel models is that, during the study time, the individuals or units in lower levels may change their upper level. For instance, a pupil may transfer from one school to another one or a patient may being admitted in different hospitals during his/her several admissions. Note this can cause difficulties in estimating the school effect or hospital effect. This problem is known as 'cross classification' problem. Suitable macros (within MLN) exist to analyse this.

Non-linear multilevel models can also be considered. Examples of this type of multilevel models are the multilevel log-linear model, the multilevel logistic model and the multilevel survival model. These can also be analysed using recent developments in Mln[1] (Goldstein H. 1995)

[1] Software for analysing a data with a multilevel structure

7-2-2 : Use of Multilevel Models in analysing the pattern of asthma admissions (further analyses using this type of models):

Our data set has clearly a hierarchical structure. Asthma admissions are nested within individuals, individuals have been treated by different consultants or in different hospitals. Consultants or hospitals are included, respectively, in different hospitals or different cities. In addition to the hierarchical structure, the data has some unique aspects that makes it very difficult to be analysed by usual methods. First of all, we have repeated admissions or repeated times free of admission for each patient. Second, the number of repeated admissions or repeated times free of admission varies widely from one individual to another - it varies from 1 to 79 -. Third, repeated times free of admission of different patients have not been measured at similar times. Note that times free of admission of a particular patient are not independent (see section 6-2).

If we intend to use the survival models to analyse times free of admission, then we should deal with a survival model which permits repeated observations for each patient as well as the dependency between these observations. The consideration of the hierarchical structure of the data in such a survival model makes it a multilevel survival model. In this case, not only can we estimate the variation or the correlation coefficient between times free of admission of a particular patient but we can also estimate the variation between patients as well as the variation between consultants or hospitals in times free of admission i.e. we can estimate the amount of variation in times free of admission corresponding to different levels. Such models can be both theoretically and practically complex. In addition to these problems, patients

can be admitted to different hospitals or be treated by different consultants at different occasions. This involves a cross-classification problem in estimating the parameters of the model. There are two versions of multilevel survival models, the Multilevel Log Duration model and the Multilevel version of Cox Proportional Hazards model. These become complex when extended to the multilevel settings.

Note that in analysing our data we have completely ignored the hierarchical structure of the data to be able to analyse times free of admission (chapter 5). We have considered different times , such as first, second and third times free of admission, separately. In theory, not considering the hierarchical structure of the data causes us to lose some information. However, we have not investigated this. Another problem which arises by not considering the hierarchical structure of the data is that the responses corresponding to patients who have been treated in the same hospital or live in the same city (i.e. the patients who are in same unit in upper level) may not be independent. The reason is similar to the reason which stated for dependency of repeated measures within a particular individual e.g. a particular hospital or consultant or city may have similar effect on all times free of admission of those patients who are nested within this variable.

We can consider also a multilevel log linear model (with number of later admissions at lowest level if we intend to analyse the pattern of later admissions or with number of first admissions at lowest level if we intend to analyse pattern of first admissions) or a multilevel logistic model (with proportion of returning to hospital at lowest level) but at time we decided to do so we were already out of time to end the research.

7-3 : Problems and Methodological Issues:

So far in different chapters we have used different statistical models to analyse the pattern of first and later asthma admissions. In this section we first address some problems and review some general approaches in this research. Then we present an alternative model to be used in section 4-3, where a weighted regression model was used to analyse the means of later asthma admissions in relation to different factors. At last we discuss the use of cumulative conditional logistic model in fitting common coefficients to different cut points of probability distribution function of later asthma admissions and compare its advantages to conventional logistic model applied to variety of cut points.

Throughout this thesis we have dealt with first and later asthma admissions separately. We distinguished between a patient's first asthma admission and first recorded asthma admission by considering, at least, 3 years free of admission before first recorded admission. If the asthmatic patients had not any previous asthma admissions within, at least, 3 years before first recorded admission we decided to consider his/her first recorded admission as his first admission. In section 2-2 we used patients' first time free of admission to investigate the precision of this decision. Table 2-2-1 showed that nearly 90% of second admission (of those patients who had second admission) had happened within 3 years after first admission. Here we would like to mention a possible bias in results of this table. The reason is that as year passes (from 1984 to 1992), only first times free of admission of those patients are considered who had their second admission sooner than other patients. One

may use the following approach to check whether the first admissions has been identified correctly or not.

Suppose a first admission occurs in 1980 or earlier, but no later admission in 1981-1983, then some later admissions in 1984-1992. This first recorded admission will be wrongly regarded as the first admission.

The probability of the above event will depend on the date of first admission, and in general will be difficult to estimate.

Consider a first admission on the last day of 1980. For this we simply want the probability that the second admission (if any) occurs in either the 4^{th}, 5^{th}, ..., 12^{th} year after first admission. We could estimate this most reliably by adding proportions of

2^{nd} admissions 1992	(among 1988 first reported admissions)
2^{nd} admissions 1992	(among 1987 first reported admissions)
.....	.....
.....	.....
2^{nd} admissions 1992	(among 1980 first reported admissions).

Data was not available to calculate all above proportions. We calculated these proportions for those patients whose first reported admission was in years 1988 to 1984. These proportions were 0.021, 0.014, 0.013, 0.0086 and 0.0098. The sum of these proportions are 0.066 i.e. the probability of having second admission (for a patient with first admission in year 1980) in either 4^{th}, 5^{th}, 6^{th}, 7^{th} or 8^{th} year after first admission is 0.066. Note that both last two proportions are less than 0.01. If for the 9^{th} to 12^{th} year after first admission this remains below 0.01 then the probability of having a second admission in 4^{th} to 12^{th} year after first admission is about 0.11. It implies that about 89% of patients who had their first admission in year 1980, their second admission are not considered as first admission.

We would also like to mention the general approach which we have used throughout this research to testing the interactions. We have always forced the related main effects to be in the model when interaction terms were tested to be included in the model. Note that the interpretation of interactions are not possible when the related main effects are not presented in fitted model. If the interaction was not significant then the model was refitted without the interaction and also if any main effect was forced in the model, it was removed as well.

In section 4-3 we used a weighted regression model to analyse the means of later asthma admissions in relation to different factors. Here we present an alternative model which was possible to be used instead of weighted regression. We think even the events of later admissions of an asthmatic patients are not independent, therefore a Poisson model could not be applied to these events, but we could consider a Poisson process for analysing the events of later asthma admissions of a group of patients who are in a particular cell of contingency table. Suppose X is the number of later asthma admissions of an asthmatic patient in a particular combination of factors age, sex, year of first admission (cohort) and city of first admission. If X could be assumed to be a Poisson random variable then,

$$P(X=x|\theta) = e^{-\theta}\,\theta^{x}/x!$$

where $\theta>0$ is the parameter of Poisson distribution (i.e. mean of number of later admissions) for the asthmatic patient and x=0, 1, 2,.... Note that $\log(\theta)$ can be related to a linear predictor $\eta=\beta'Z$ where Z is a set of predictors and β can be estimated from the data. Hence the total number of later admissions corresponding to N_i asthmatic patients who are in this particular cell of contingency table is then,

$$T_i = \sum_{j=1}^{N_i} x_{ij}$$

where i and j are, respectively, the cell and patient's index. T is a Poisson random variable with parameter $N_i\theta_i$. We have,

$$\text{Log}(N_i\theta_i) = \text{Log}(N_i) + \text{Log}(\theta_i)$$
$$= \text{Log}(N_i) + \beta'Z$$

Thus to specify the model correctly we must include the term $\log(N_i)$ as an explanatory variable with a coefficient of 1, that is $\log(N_i)$ must be taken as an offset for the model. This model could be fitted using GLIM. In this thesis, in chapter 3, when the sample mean $\bar{X}_i = T_i/N_i$ and sample variance s^2_i were calculated for cell i, it was found, for many cells, that $\bar{X}_i$ and s^2_i were very different. This showed a Poisson model would be wrong.

In section 4-6 we illustrated the use of cumulative conditional logistic model for fitting a single logistic model to several cut points of probability distribution function of later admissions. Note that different factors (and terms) were included in separate logistic models which were fitted to cut points P(X>0), P(X>2|X>0), and P(X>3|X>2). We found out that logistic models, each fitted to a single cut points, include different factors. For instance, the probability of having more than zero later admission (i.e. having at least one later admission) was significantly related to two factors age, sex and their interaction while the probability of "having more than 3 later admissions given that patient has already 2 later admissions" was related to factor "City". We believe the results from the logistic model fitted to all 3 probabilities simultaneously, are more reliable. This approach is even more useful when the number of available cases decreases as the cut points increase.

Large counts lead to significant results which are not important. Multiple testing leads also to "significant" results which are not genuinely significant. So

we pay more attention to comparing actual and fitted counts (plots) than to formal significance.

Chapter 8

Conclusions

In chapters 2 to 6 we have carried out various analyses of the pattern of asthma admissions and its relation with various factors. In this chapter we report the results of each chapter briefly. We also try to link the results from different chapters, as well as to mention the advantages and disadvantages of the methods which have been used in each chapter, to come to overall conclusions for pattern of asthma admissions.

At the beginning, it is necessary to mention that the data file which was used through the whole research did not include all asthma admissions which have occurred in Scotland between 1981 and 1992. We carried out some modifications to prepare the data set for next analyses. The most important modification was to identify the first admission of asthmatic patients. We considered at least a 3 year support to identify first admissions between 1984 and 1989. Later, in section 2-2, we showed that 90% and 99% of those patients who had returned to hospital, returned, respectively, within 3 years and within 6 years after previous admission. This implies the choice of first admissions has been relatively reliable. Note the final data set contained the asthma admissions of those asthmatic patients whose first asthma admissions occurred between the years 1984 to 1992. Although by this choice we lost the opportunity to report the crude number of asthma admissions in different years, it enabled us to study

the whole pattern (up to end of year 1992) of asthma admission of all included patients. Later, in chapters 3 and 4 we studied this pattern in a 3 year horizon after first asthma admission.

In chapter 2, 'Descriptive Analyses', we carried out simple comparisons, using plots, tables and simple indices, to discover the basic characteristics of asthma admissions. We showed that there is a strong seasonal pattern for asthma admissions which has repeated itself through years 1984 to 1992. Over these years, the numbers of first asthma admissions has increased (see plot 2-4-1). In December 1992 the number of first admissions was 627 which is 1.5 times the number of first admissions in similar month in year 1984 (compare with 421 first admissions in December 1984). The mean of age of these patients were very close (21.4 years in 1984 and 21.5 years in 1992). The seasonal pattern for younger patients was much stronger than the older ones. Younger patients (under 25 years old) came to hospital, as a first time admission, more in August, October and November than in other months of the year. The patients who were more than 25 years were admitted, at the first time, more around December and January and the corresponding minimum number of admissions was around July. We did not find any evidence that those patients whose first asthma admission had occurred in a particular month are, in a 3 year horizon after first admission, more or less likely to return to hospital (see plots 2-4-5 and 2-4-6).

We discovered that first admissions increased during years 1984 to 1992 (see plot 2-5-1). The sharp increase happened in years 1987, 1990 and 1991. There are actually two or three jumps in number of first admissions, one in between year 1986 and 1987, one in between years 1989 and 1990 and the third one between 1990 and 1991. It is likely that these jumps are related to some changes in health service policies, for example hospitalisation policy, rather

than to a real change in severity of the disease. The important increase in first asthma admissions has occurred during years 1989 to 1991 with two jumps, one in 1990 and another one in 1991. In these two years, the number of first asthma admissions has increased by 28.7%. Later we showed that the above conclusions are valid only for babies (0-2 years), young adults (15-25 years) and adults (more than 25 years), with the sharpest increase corresponding to babies. There was no evidence of any considerable change in first admissions corresponding to children (3-14 years) (see plot 2-5-2.)

We considered the number of later admissions in a 3 years horizon in each cohort of first admissions in each age group (see plot 2-5-4) and showed that there was little change in the number of later admissions per patient (except for babies). Comparing this result with plot 2-5-2 may lead us to the very important result that recent increase in number of asthma admissions in Scotland corresponds to an increase in first admissions (i.e. new asthmatic patients) (and only in age groups 0-2 and more than 15 years) and not to previously known or treated patients.

In 2-7 and 2-8 we discussed also the pattern intensity of later asthma admissions and discovered that in overall, in different age groups, the mean intensity of returning to hospital decreases as the year since the first admission increases and the pattern of decrease is similar for all age groups. Initial intensity is greatest for babies, but after 5 years all age groups have mean intensity about 0.1 per year. Note that after 5 years a baby is no longer a baby. The year of first asthma admission has not any effect, or maybe a very small effect, on intensity of later asthma admissions

In chapter 3 we distinguished the four types: non- emergency/emergency and first/second diagnosis of first admissions. We then fitted loglinear models, one for each type, to investigate the relation between numbers of first

admissions and different factors. The main effects and the same 2-factor interactions were fitted to a grouped contingency table. Validation was on the whole successful.

In 3-9, conclusions suggested by the models for counts of the four types of first asthma admission were presented. Plots of estimated expectations of counts were shown illustrating :

(a) different age patterns in cities (for all years and both sexes);

(b) different trends in cities and age-groups (for both sexes);

(c) the different sex ratios for adults and children/babies (in all cities and years).

In chapter 4, Weighted Regression was used to investigate the relation between later asthma admissions, in a 3 year horizon after first admission, and a number of factors. The Logistic model also was used to model, at certain point, the probability function of returning to hospital.

The weighted regression models indicated that the means of later admissions of those patients whose first admission is type 1 or 3 are not related to any of the considered factors.

Fitted models to the mean of later admissions of patients whose first admissions were type 2 indicated that babies return to hospital more frequently than children and adults, and adults return more frequently than children. Among babies, the age group is the only factor which is related to mean of later asthma admissions i.e. mean of later asthma admissions of babies is not even related to sex. For two other age groups (children and adults), the mentioned mean, in addition to age group, is related to sex, the interaction between age group and sex (i.e. the effect of age group is different for male and female), and also to year of first admission. Girls and women return to hospital more frequently than males. Note we discovered before that male first admissions are

significantly more frequent than female first admissions. This may indicate that males who are admitted to hospital for first time, are not on average as ill as female patients. There is some indication that the tendency of females to return more often than males is weaker in adults than in children.

We discovered also that the mean of later admissions of patients whose first admission is type 4 is significantly related to two factors "age group" and "sex" and both children and adults are less likely than babies and that adults are less likely than children to return to hospital. Note this recent result is different from that we got for first admission of type 2. Once again, the mean of later admissions of females is greater than males' mean of later admissions.

Probability tables of having 0 (i.e. not returning to hospital), more than 2 and more than 3 later admissions, are shown in chapter 4 as well. These tables confirm the importance of age and sex. The probability of "Not returning to hospital" for patients with first admission of types 1, 2, 3 and 4 are respectively, 0.73, 0.67, 0.85 and 0.77. It indicates that patients with first admission of type 3 (non-emergency second diagnosis) have the least chance of returning to hospital. Table 4-5-14 indicated that the probability of "Having more than 2 later admissions" for patients whose first admission was type 2 is 0.09 which is more than 4 times the probability of same event for patients with first admission of type 3. These tables indicate that first admissions of type 2 and 3 are always opposite to each other. For instance, table 4-5-13 indicates that the smallest probability of "Not Returning to Hospital" is due to those patients whose first asthma admissions are type 2 while the largest probability of "Not Returning to Hospital" is due to the patients with first asthma admission of type 3. Tables 4-5-14 and 4-5-15 show that the largest probability of either "Having More Than 2 Later asthma Admissions" or "Having More Than 3 Later Asthma Admissions" is due to patients with first asthma

admissions of type 2 while the smallest of these probabilities belong to those whose first asthma admissions are type 3.

In chapter 4 we have illustrated the use of cumulative conditional logistic model to fit a single model to different cut points of conditional probability distribution function of later asthma admissions. Again this showed the effect of age and sex.

In chapter 5 the Cox Proportional Hazard model was used to model first, second and third times free of admission using age, sex, year, city as well as the length of the most recent stay in hospital. When the second and third times free of admissions were modelled, we used previous time(s) as well as previous length of stay in hospital as covariates. These models indicated that the factors age, length of stay, and, when applicable, previous time(s) free of admission as well as previous length of stay in hospital, were significant factors for all times free of admission but as a patient progresses from first to second and then to a third time free of admission, the effect of age (at time of first admission) becomes less important. The effect of age was consistent with the effect which was reported in previous chapters. We discovered that patients who have shorter previous time(s) free of admission are more likely to return to hospital i.e. they have a shorter next time free of admission as well. The effect of recent length of stay or previous length of stay was opposite to the effect of previous(s) time(s) free of admission i.e. those patients who have shorter recent length of stay or shorter previous length of stay in hospital are less likely to return to hospital. The patient who is more seriously ill returns sooner.

In chapter 6 we investigated the distribution of complete times free of admission of a sample of patients. We could not fit a common distribution to times of all 6 patients (having at least 15 admissions) who were in our systematic sample but it appears that for those who have relatively small

number of admissions the Log Normal and for those who have the largest number of admissions the exponential distributions fit well. Of course the results of 2-7 show that the exponential distribution (Poisson Process) can not be typical of the majority of patient. In this chapter it was also shown that each time free of admission of a particular asthmatic patient is at most related to two previous times free of admission. The severely ill return sooner.

We were told by an expert (Burns, H. 1995) that nowadays, wheezing inclines to be diagnosed as asthma. He believes that 10 years ago, allergic and/or ineffective aetiology would be separately diagnosed while in these days they all considered as asthma. Burns thinks some coding drift, but also some genuine increase in asthma, especially among babies (0-2 years old), has happened. He suggested also that the awareness of greater risk to babies has caused some non-genuine admissions for babies. We were also told that inhaled steroids nowadays reduce frequency of attacks. Note we did not find any evidence to believe there has been any important change in number of later admissions over period of study. Burns mentioned that a male's smaller tendency for later admissions (compared to an equally ill female at time of first admission) could be a consequence of this fact that males grow faster, so airways get large enough to avoid further admissions.

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Appendix 1

Definitions of Variables

In this appendix a list of all existing covariates in the data file and their definitions are listed. Note that some of these covariates existed in the original file while some of them were created when the modifications on the original data file were carried out. These modifications are mentioned in section 2-1.

We mention that a single covariate may be used differently throughout the analyses in this research e.g. in different chapters the covariate "Age" is considered as a categorical variable with different levels.

Linked data :

Is a special data providing a complete list of each patient's admissions (within years 1981-1992) in a medically closed area (Scotland).

Asthmatic patient :

Is defined as any person who has been hospitalised at least once in one of the Scotland's hospitals with asthma diagnosis either as first or second reason of hospitalisation. In this research only those asthmatic patients whose first asthma admissions have occurred between dates 1/1/1984 and 31/12/1992 are considered.

Hospital asthma admission :

Is defined as any patient's admission to any hospital throughout Scotland which has occurred because of asthma disease.

State of asthma admission :

In our research each asthmatic patient is either in "Admitted state" or "Not admitted sate". Those asthmatic patients who are already hospitalised in any hospital, are in "Admitted state" and those who are out of hospital are at "Not admitted state". Note that the asthmatic patients who are already in hospital, are not at risk of being admitted while those who are out of hospital are.

First admission :

Is defined as the first event of admission because of asthma disease (i.e. the first event of hospitalisation) to any hospital throughout Scotland.

First recorded admission :

Is defined as the first recorded admission because of asthma disease to any hospital throughout Scotland. Note that the first recorded admission is not necessarily the first admission of the asthmatic patient i.e. one asthmatic patient may have an admission due to asthma disease (suppose as the first admission) before the recording procedure began.

Later admission :

Is defined as all asthma admissions of an asthmatic patient which occur after his/her first admission.

i-th time free of admission :

Is defined as the time interval between the date of i-th discharge (i.e. the discharge which is due to i-th admission) and the date of (i+1)th admission or the date of death or the end date of follow up (i.e. 31/12/1992). Note that a time free of admission may be complete or incomplete. Times free of admissions are in days.

Complete time free of admission :

The i-th time free of admission of an asthmatic patient is complete if the (i+1)th admission has occurred for the patient i.e. the ith time free of admission of an asthmatic patient is complete if he/she has (i+1) admissions.

Incomplete or censored time free of admission :

The i-th time free of admission of an asthmatic patient is incomplete or censored if the (i+1)th admission has not still occurred for the patient at end of follow up. The end point of such times free of admission is 31/12/1992 or earlier death.

i-th length of stay in hospital :

Is defined as the time interval between the date of i-th admission and its next immediate discharge date or the date of death. Length of stay in hospital is in days.

Person-based asthma admissions :

Is defined as the number of persons who have caused all hospitals asthma admissions in a time interval i.e. in a year or in a month.

Episode-based asthma admissions :

Is defined as the number of hospital asthma admissions that have occurred in a time interval.

Age of patient :

The covariate age has been used as a categorical variable through out the research. The levels of this factor are :

1- 0 - 2 years old (babies)

2- 3 - 6 years old (young children)

3- 7 -14 years old (children)

4- 15-25 years old (young adults)

5- More than 25 years old (adults)

* In most of chapter 3 and the whole of chapter 4 age groups 2 and 3 were combined to form one group and groups 4 and 5 were pooled to form a third group.

Marital status :

This covariate has 5 levels which identify the marital status of the asthmatic patient. At initial analyses the marital status was used with all its 5 levels but later only two first levels which were due to single and married patients were used. Levels of marital status are :

1- Never married - single

2- Married (includes separated)

3- Widowed

4- Other

5- Not known

Admitted from :

This covariate identifies the place which the asthmatic patient is admitted from. It has 4 levels which are :

1- Home (usual address)

2- Other NHS hospital (Inpatient, Short Stay or Day Bed facilities only)

3- Other unit in this hospital (Inpatient Facilities or Day Bed Units only)

4- Other

Admission Type :

Identifies the type of admission for an asthmatic patient. It has 9 levels. In most of analyses the first 4 levels together and the last 5 levels together were mixed and labelled, respectively, as non-emergency and emergency admissions. The levels of this covariate are :

Non-Emergency Admissions	Emergency Admissions
1- Deferred admission	5- Emergency - Deliberate Self-Inflicted Injury or Poisoning)
2- Waiting List/Diary/Booked	6- Emergency - Road Traffic accident
3- Repeat Admissions	7- Emergency - Home Accident (Includes Accidental poisoning in the home)
4- Transfer	8- Emergency - Other Injury (Includes Accidental Poisoning other than in the home)
	9- Emergency - other (excluded Accidental poisoning)

Discharge code :

Identifies the type of discharge from the hospital. It has 9 levels which are:

1- "irregular" - emergencies self discharge

2- Home

3 - Convalescent Hospital or Home

4- Other Hospital

5- Local Authority Care

6- Transfer to other specialty in same hospital

7- Died (PM)

8- Died (No PM)

9- Other

Category of patient :

Identifies the category of the asthmatic patient. It has 6 levels which are :

1- Amenity

2- Paying

3- NHS

4- Overseas Visitor - Liable to pay for treatment

5- Overseas Visitor - Not liable to pay - reciprocal arrangements

6- Special Arrangements

Type of facility :

Identifies the type of facility which the asthmatic patient has used during his/her hospitalisation in hospital. It has 6 levels which are :

1- Inpatient Admission

2- Day Case Remaining Overnight in inpatient facilities

3- Five Day Ward

4- Day Bed Unit

5- Day Case Inpatient Facilities

6- Day Case Other

Specialty :

Identifies which the specialty which the asthmatic patient has been hospitalised or treated in. This covariate has so many levels which are not necessary to be mentioned here. The most common specialties which contains nearly all asthmatic patients are :

1- General Medicine (Code 16)

2- Respiratory Medicine (incl. Respiratory TB) (Code 28)

3- Medical Paediatrics (Code 40)

4- GP (other than obstetrics) (Code 73)

Type of diagnosis :

Identifies that asthma is either the first or the second reason of hospitalisation i.e. asthma is the first or the second diagnosis. This covariate has 2 levels which are :

1- Asthma is the first diagnosis.

2- Asthma is the second diagnosis.

First Diagnosis :

Identifies the first reason for which the asthmatic patient has been hospitalised.

Second Diagnosis :

Identifies the second reason for which the asthmatic patient has been hospitalised. Note that in this case, the first reason of hospitalisation (or the first diagnosis) may be something different from asthma disease.

Type of asthma :

Identifies the type of asthma. This factor has three levels. For full description of type of asthma we refer the reader to International Classification of Diseases version 9 (ICD9), WHO Publication.

City :

This covariate identifies the city in which the asthma admission has occurred. In this research, the city which the first episode of asthma admission has occurred in, has been considered as the city in which the asthmatic patient lives in.

Cohort i :

Is defined as the cohort of all asthmatic patients whose first episode of asthma admission has occurred in year i, i=1984 to 1992.

Observed time :

Is defined as the time interval between the date of first admission to any hospital in Scotland and the end date of follow up (31/12/1992) or earlier death.

Appendix 2

Table 1: List of administrative areas which are defined as a particular city.

City	Post Code	Region	Administrative districts approximating the post codes
Aberdeen	AB	Grampian	Grampian
Dundee	DD	Part of Tayside	City of Dundee, Angus
Edinburgh	EH	Lothian+ Part of Borders	Lothian, Tweeddale
Glasgow	G	Part of Strathclyde	Bearsden & Milngavie, Clydebank, Cumbernauld &Kilsyth, Dumbarton, Eastkilbride, Eastwood, Glasgow City, Strathkelvin
Motherwell	ML	Part of Strathclyde	Clydesdale, Hamilton, Monklands, Motherwell
Kilmarnock	KA	Part of Strathclyde	Cumnock & Doon Valley, Cunninghame, Kilmarnock, Kyle & Carrick
Paisley	PA	Part of strathclyde	Argyll & Bute, Inverclyde, Renfrew, Western Isles

Table 2: Estimated populations in different age groups and years, Annual Reports (1984-1992), General Registrar Scotland.

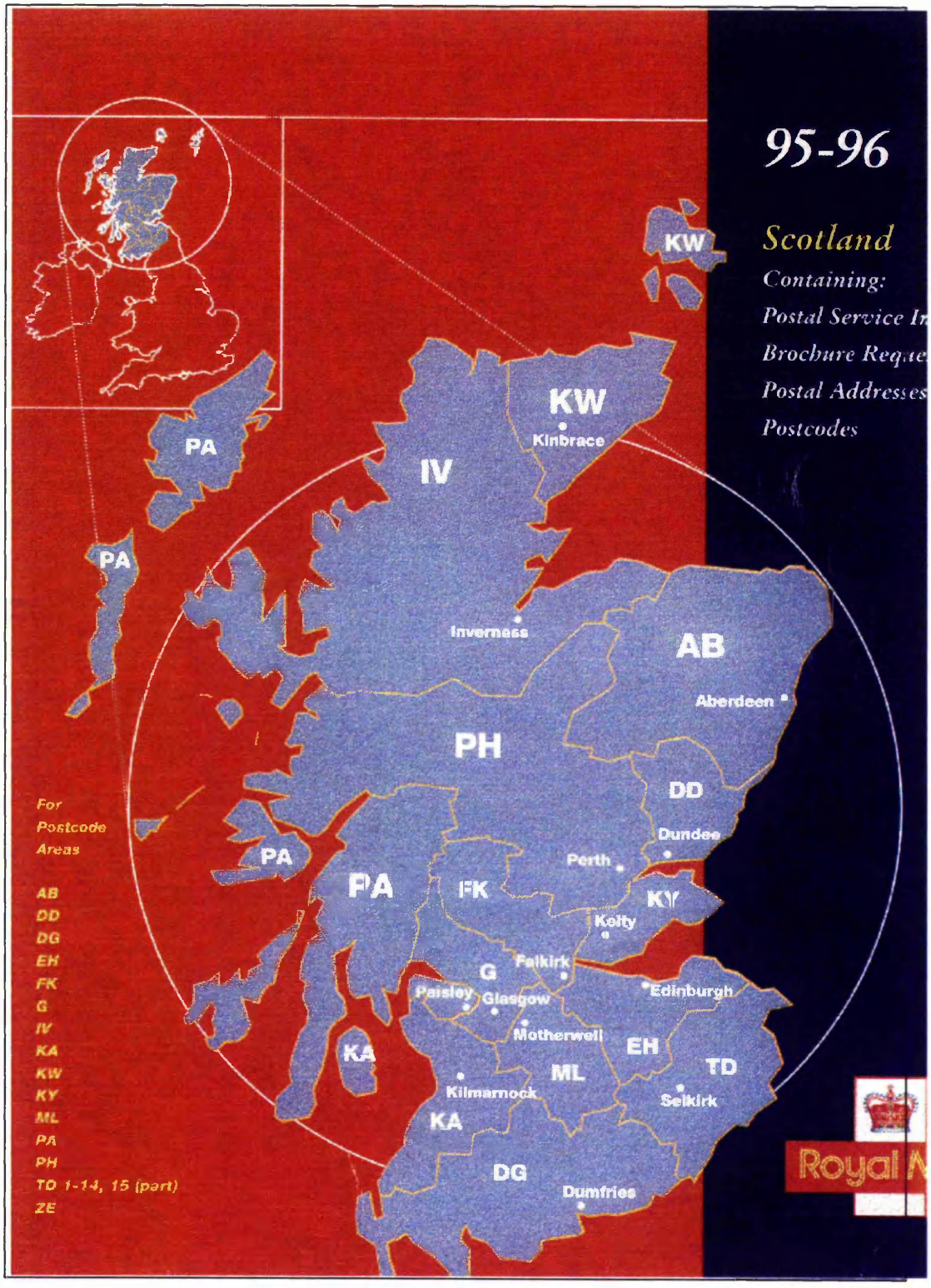
	0-2 years	3-6 years	7-14 years	15-25 years	More than 25	Total
1984	193842	256100	569990	966404	3159386	5145722
1985	192450	261616	545017	960954	3176472	5136504
1986	193979	261456	524549	953469	3187560	4121013
1987	196189	257655	511910	939479	3206896	5112129
1988	196910	254045	505438	914308	3223300	5094001
1989	195521	255147	504187	885293	3250552	5090700
1990	194611	257936	504661	862498	3282694	5102400
1991	193728	262051	504198	831120	3308903	5100000
1992	195362	260681	510453	809381	3334221	5110100
Total	1752595	2326687	4680403	8122906	29129984	46012572

Table 3: Total of estimated populations in years 1984 to 1992, in different age groups and sexes, Annual Reports (1984-1992), General Registrar Scotland.

	0-2 years	3-6 years	7-14 years	15-25 years	More than 25 years	Total
Male	897957	1191074	2400115	4144310	1599645	22232101
Female	854635	1135613	2280288	3978596	15530339	23770471

* Numbers in this table were used to estimate the average rates (over 1984-1992) in different sexes and different age groups.

Map1: Post codes in different areas of Scotland



Map 2: Administrative areas in Scotland