CHAPTER 3

3. STATISTICAL METHODS

3.1 INTRODUCTION

This chapter explains the statistical methods used for the analysis of the data gained during this study of the Physiotherapy Department. During the initial analysis of the department, it became apparent that there were probably capacity constraints. To confirm that there was indeed a shortage of staff, the physiotherapists agreed to complete timesheets and statistical methods were used to analyse the timesheets and determine available capacity. Statistical tests were also undertaken to determine standard times for treatments and whether work could be standardised across treatment areas within the Physiotherapy Department.

3.2 TIMESHEETS

To confirm that there was indeed a shortage of staff, the physiotherapists agreed, during the second workshop, to develop and complete timesheets. If concrete evidence is available, it is much easier to motivate for additional personnel from authorities. The agreement from the staff was to complete the timesheets for a period of six months.

Subsequently the development of the timesheets in conjunction with the supervisors followed (See Appendix 1). Each treatment area of the department required different timesheets as the direct patient care or treatment types differed in each area. Each supervisor (chief physiotherapist) also indicated the standard time various treatments should take. The supervisors were of the opinion that if time spent on a patient is less than the standard time indicated, treatment of the patient was not adequate.

There are three main sections in the timesheets; these sections are: Direct patient care; indirect patient care and "other activities". Direct patient care includes all hands-on treatment of patients. Indirect patient care includes education of the caregiver, teaching the patient and/or the caregiver how to manage the disease; ward rounds; contact with doctors, nurses and caregivers, as well as waiting time. "Other activities" include meetings, administration, their personal education and development, education of other groups (such as nurses and doctors) as well as personal time such as tea breaks and lunch.

The difference between education and management in indirect patient care is:

Education is teaching the patient and or caregiver about a disease, what the disease is and what the symptoms are and how to cope with the disease.

Management is teaching the patient and, or the caregiver how to manage someone with the disease. Typically this will include the medication they need to take, how often and what type of exercises they need to do or how often they need to come back for check-ups etc.

3.3 STATISTICAL ANALYSIS

Microsoft Excel was used to analyse the data obtained from the timesheets. Statistical analysis was performed to determine:

- Standard times for treatments,
- Whether there was sufficient capacity available in the department as a whole (what the load and required capacity was over a six-month period) and
- Whether standardisation could take place across treatment areas.

The approach followed was to first compare the various treatment times to the standard times given by the supervisors. This allows for the conclusion that either the standard times are correct or not, and if not, perhaps whether the standard times need to be adjusted, or whether we should conclude that treatments are consistently substandard. The next step would be to compare performance times, of similar treatments in different treatment areas. This would indicate the possibility of standardising certain treatments across treatment areas. Thereafter a comparison was made of the percentage split between the time the physiotherapists spent on direct patient care, indirect patient care and "other activities" in each treatment area and the possible reasons were identified. This indicates the difference between treatment areas in time spent on various activities and whether there are valid reasons for the time spent or whether there may be an opportunity to optimise times spent with patients. The amount of time needed to treat all the patients that require physiotherapy was then used to calculate the number of physiotherapists required in the department, as direct patient care forms the most critical part of the physiotherapists duties.

To compare the treatment times with the standard times the confidence intervals of the mean of treatment times were calculated and compared with the standard times. Standard times, skewed away from the middle, were a cause for concern and indicate that rework was probably necessary. The confidence intervals were prepared for each individual treatment type. The assumption made to calculate the confidence intervals was that the variance was unknown, but the times of different replications of the same treatment service, had a normal distribution. For treatments where 30 or more observations were available, we assumed the distribution of the sample means has an approximate normal distribution (Hines and Montgomery, 1980). The central limit theorem indicated that under general conditions the distribution of the sample means had an approximate normal distribution as the sample size (*n*) increased (Lehmann, 1986). Therefore it can be assumed that the sampling distribution is a normal distribution for n>30 (Hines and Montgomery, 1980). Only those treatments with sufficient (n>30) data points were discussed. The confidence intervals were only calculated for n larger than 30. Hines and Montgomery (1980) supported the use of the normal distribution for n>30.

Subsequently a comparison between specific treatment times of similar activities in different treatment areas helped determine whether standardisation across treatment areas was possible. Hypothesis tests on the means of the similar treatments were made to determine whether the treatment times were the same or not. Again the assumption for treatments where more than 30 samples of specific treatments were available, based on the central limit theorem, was the normal distribution.

The percentage of time spent by a physiotherapist on direct, indirect treatment and "other activities" was determined for each treatment area. The various treatment areas had a different distribution of time across the direct, indirect or "other activities" components due to the nature of the treatment area. The supervisors confirmed the results.

The load and capacity was then determined by calculating the average time required per treatment area to treat all the patients that needed hands-on treatment or direct patient care. The average time required per day per treatment area, to treat all patients, summed for all treatment areas, gave the total number of hours, for which Physiotherapy treatment was required in the department. Based on the average percentage of time spent on direct patient care the number of physiotherapists the department required was calculated. A comparison between this number and the current number indicated the capacity constraints.

Insufficient capacity will influence quality of treatments, cost of patient care as well as quality of work-life for physiotherapists. Excessive capacity would lead to unnecessary increase in cost (Chase and Aquilano, 1995) and due to limited funds other departments would suffer. It was therefore essential to determine what the current capacity of the

Physiotherapy Department was, as well as the current load to determine what the need was in the department. This information was also required to determine the optimal capacity levels.

3.3.1 Confidence Intervals

The confidence interval can be interpreted as follows: If many random samples are collected, in (1- α) 100% of the samples the true value of the parameter will be included in the interval. Therefore, it does not make sense to use the probability indication. It makes sense to indicate the percentage (%) confidence we have that it does contain the relevant parameter.

The confidence interval specifies both the upper and lower limit within which (1- α) 100% of the samples will contain the actual parameter. Ideally the confidence interval should be a relatively short interval but indicated with a high percentage of confidence.

The reason for calculating the confidence intervals on the mean was to determine whether the standard times were within the confidence intervals for the mean of each treatment type and therefore accurate. The decision was to use the 95% confidence interval for this exercise.

Assume the following nomenclature

Lower Limit - l

Upper limit - u

Probability – P

Mean - μ

α is the confidence coefficient.

$$l \leq \mu \leq u \quad (3.1.)$$

$$P\,(l \leq \mu \leq u) = 1 - \alpha \quad (3.2.)$$

We assume that the sampling distribution is approximately normal if the conditions of the central limit theorem apply.

$$P\,(-z_{\alpha/2} \leq Z \leq z_{\alpha/2}) = 1 - \alpha \quad (3.3.)$$

By rearranging from the standard normal distribution, we obtain the following:

$$P\left(X - \frac{(z_{\alpha/2})\sigma}{\sqrt{n}} \leq \mu \leq X + \frac{(z_{\alpha/2})\sigma}{\sqrt{n}} \right) = 1 - \alpha \quad (3.4.)$$

$$l = x - \frac{(z_{\alpha/2})\sigma}{\sqrt{n}} \quad (3.5.)$$

$$u = x + \frac{(z_{\alpha/2})\sigma}{\sqrt{n}} \quad (3.6.)$$

In the exercise the confidence intervals were calculated by first calculating the sample average (x) and the sample standard deviation (σ) for each data set or times for specific treatment. Each data set was the various times for a specific treatment type in a specific treatment area. The AVERAGE and STDEV functions were used in Excel for this purpose. Then the CONFIDENCE function was used to calculate the confidence interval.

3.3.2 Hypothesis Tests

To measure empirical evidence we use hypothesis tests (Hines and Montgomery,1980). Normally formulation of hypothesis tests is as a pair of incompatible statements about the value of a parameter. The statement is about the population or distribution under study and not the sample taken. The goal is to decide whether a formulated hypothesis is correct or not. To make this decision it needs to be determined whether there is strong evidence against the null hypothesis (H_0) and in favour of the alternative hypothesis (H_1). In the study of the Physiotherapy Department, hypothesis testing was used to verify the theory that similar treatments in different treatment areas should be the same. The use of hypothesis testing could extend to determine whether experimental conditions have changed or to determine conformance.

Two possible errors can occur when making use of hypothesis testing.

- Rejecting the null hypothesis when it is correct, this is called a type I error and the probability of this error occurring is given the symbol α

or

- Accepting the null hypothesis when it is incorrect, this is a type II error and the symbol β indicates the probability of this error occurring.

Tests need to carried out in such a way that the probability of both types of errors are minimised

The true value of the parameter determines the value of β. We can consider β as a measure of the ability of the test to determine the variation from the null hypothesis H_0. The location of the region in which the values of test statistic are, determines the value of α. The value of α can be set at a desired level; therefore, the rejection of H_0 is a strong conclusion. Since β is dependent on the sample size and the extent to which the null hypothesis (H_0) is false - we never accept H_0 we merely fail to reject the null hypothesis. Therefore as a default conclusion it is a weak conclusion. There are therefore two choices, we reject the null hypothesis or we fail to reject the null hypothesis. When doing hypotheses testing we are in fact interested in the validity of the alternative hypothesis. If there is insufficient evidence in favour of the alternative hypothesis (H_1) we reason that the data obtained is not particularly unlikely under the null hypothesis (H_0)

The smallest level of significance to reject the null hypothesis H_0 is called the P-value of the test. The P-value is a significant value because it is useful to know the precision level with which one could reject the null hypothesis.

A hypothesis test consists of the following:

- The null hypothesis (H_0) and the alternative hypothesis (H_1).
- The test statistic, T
- The region in which the values of T will lead us to reject H_0 - the critical region
- The probability of making a type 1 error - the significance level, α

In this instance the hypothesis was set up to determine whether the same type of treatment (direct patient care) in different treatment areas, x and y, needed the same amount of time and could therefore be standardised.

$$H_0: \mu\_x \text{ (direct patient care)} = \mu\_y \text{ (direct patient care)} \qquad (3.7.)$$

$$H_1: \mu\_x \text{ (direct patient care)} > \mu\_y \text{ (direct patient care)} \qquad (3.8.)$$

The test is called the inference on the difference in means of two normal distributions with unknown variance.

It is not clear whether the two treatment areas have the same variance in treatment times for a specific treatment type and therefore the application of two different statistical procedures is required. The first statistical procedure is for the assumption that variances are equal but unknown. The second statistical procedure is for the assumption that variances are not equal. Rejection of the null hypothesis (H_0) for both these cases indicates that the, null hypothesis (H_0) can be rejected whether the variances are equal or not.

The significance level selected was α = 0.05 this is equivalent to rejecting the null hypothesis with 95% confidence. The degrees of freedom are represented by n1+ n2 – 2.

For the first case where variances are assumed equal but unknown where X_1, X_2, S_1^2, S_2^2 are the sample means and sample variances. Since both S_1^2 and S_2^2 estimate the common variance, the combination of the two is possible.

$$S_p^2 = \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{(n_1 + n_2 - 2)} \quad (3.9.)$$

To test the hypothesis we compute the test statistic

$$t_0 = \frac{(X_1 - X_2)}{S_p \sqrt{(1/n_1 + 1/n_2)}} \quad (3.10.)$$

If H_0 is true t_0 is distributed as $t_{n1+n2-2}$. Therefore if $t_0 > (t_{\alpha/2,\, n1+n2-2})$ then we reject H_0 for a one-sided hypotheses.

For the second case where variances are assumed not equal and unknown where X_1, X_2, S_1^2, S_2^2 are the sample means and sample variances. There is not an exact t statistic available for testing the null hypothesis in this case. The statistic

$$t_0^* = \frac{(X_1 - X_2)}{\sqrt{(S_1^2 / n_1 + S_2^2 / n_2)}} \quad (3.11)$$

is approximately distributed as t if the null hypothesis is true. The degrees of freedom in this case would be

$$v = \frac{\{(S_1^2 / n_1 + S_2^2 / n_2)^2 \}}{(S_1^2 / n_1)^2 / n_1 + 1] + [(S_2^2 / n_2)^2 / n_2 + 1]} - 2 \quad (3.12)$$

Therefore, for variances assumed unknown, the calculation of the hypotheses is as in the description of the first case above. Although in this case the t_0^* is used for the test statistic and the degrees of freedom $n_1 + n_2 - 2$ is replaced by v. (Hines and Montgomery, 1980)

3.3.3 Other Sources of Information

In most instances, there are no hospital records of the past treatments and times of treatments. The available records in this case were of no value to compare the results obtained in this study with.

In 2000 the Physiotherapy Department performed an audit and the results of the audit were compared to the results obtained in this study. The method followed by the Physiotherapy Department was to conduct an audit in the Johannesburg Hospital on one specific day (De Charmoy and Eales, 2000). They assessed all in-patients, on this day, for pathological condition, the need for physiotherapy and the amount of time required per physiotherapy treatment and the number of physiotherapy treatments required in a day. A senior physiotherapist working in the area and a member of the university staff who teaches and supervises students within that clinical area performed the assessment of each area. The two assessors worked independently to ensure that there was impartiality in determining the needs in the wards. They used information sheets with the following parameters:

- Number of patients in the ward
- Diagnosis of the patients
- Whether or not the patients would require physiotherapy
- If the patient required physiotherapy then the choice of physiotherapy was as follows: respiratory condition, musculoskeletal, ambulation /exercise, neurological or just a check.
- The auditors estimated the number of treatment units - each unit was a 15-minute session thus the figure 2 meant half an hour of treatment.
- Finally, the auditors also estimated the number of contacts the patient should have in a day. That is if the number of units read 4 and the number of contacts was 2 then the patient was assessed to require a two-treatment session for a total of 1 hour. (De Charmoy and Eales, 2000.)

Based on this information the required number of eight-hour units was established. Thereafter it was important to determine time spent on direct patient care daily. To determine the percentage of time spent on direct patient care the auditors randomly chose physiotherapists and assigned them to assessors.

The assessor then arrived to follow the physiotherapist around for a day. The physiotherapists were not aware which day this was going to happen in an attempt to get as true a picture as possible. The assessor then documented throughout the whole day the following categories:

1. Direct patient care

2. Indirect patient care
3. Social - this involved tea, lunch, social telephone conversations i.e. anything not related directly to a patient.

This data was then put together and the average percentage of time spent on direct patient care was established. Based on the percentage of time spent on direct patient care and the number of eight-hour units required, the number of physiotherapists needed in the hospital was determined.

This study is not an accurate indication of the capacity requirements because it only gives a snapshot of conditions in the hospital on a single day. Time intervals of 15 minutes were used to indicate the time required for treatments and one would not be able to determine if physiotherapists used more or less than a complete unit per treatment.