

**THE EFFECT OF EXERCISE IN PULMONARY REHABILITATION
ON THE QUALITY OF LIFE OF CHRONIC OBSTRUCTIVE
PULMONARY DISEASE PATIENTS**

JENNIFER LEIGH BROWN

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SUPERVISOR: PROF J G BARNARD

CO-SUPERVISOR: PROF J R JOUBERT



DEPARTMENT OF SPORT SCIENCE

STELLENBOSCH UNIVERSITY

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DECLARATION

Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

ABSTRACT

The purpose of the study was to measure the responses of chronic obstructive pulmonary disease patients to an exercise programme in a South Africa setting. Nine subjects were evaluated before and after aerobic and resistance training three times a week for the total of 12 weeks. Each evaluation measured forced expiratory lung function; health-related quality of life; functional capacity; level of dyspnea; body composition; physician global evaluation; and the patient global evaluation. The exercise programme consisted of one-hour exercise sessions, three times a week for 12 weeks. The exercise sessions included elements of aerobic and resistance training of the upper and lower extremities. Functional capacity improved drastically ($p < 0.01$), as did the physician and the patient global evaluations ($p < 0.01$ and $p < 0.01$, respectively). Levels of dyspnea also improved ($p < 0.01$). Health-related quality of life improved marginally ($p = 0.03$). No significant change was noted in lung function and body composition. The study concluded that an exercise programme consisting of aerobic and resistance training improves chronic obstructive pulmonary disease patients' health-related quality of life, functional capacity and levels of dyspnea. Exercise also reduces the symptoms of chronic obstructive pulmonary disease as are perceived by the physician and patient alike. Exercise does not change lung function or body composition of chronic obstructive pulmonary disease patients. Exercise in conjunction with appropriate medical treatment has the potential to benefit all chronic obstructive patients in South Africa.

Keywords: COPD, quality of life, functional capacity, rehabilitation, exercise.

OPSOMMING

Die doel van die studie was om die reaksies te meet van pasiënte met chroniese obstruktiwe pulmonêre siekte op 'n oefenprogram in 'n Suid-Afrikaanse konteks. Nege proefpersone is voor en na aërobiese en weerstandsoefening drie keer per week vir 'n totaal van 12 weke geëvalueer. Elke evaluering het die volgende gemeet: geforseerde ekspiratoriese longfunksie, gesondheidsverwante lewenskwaliteit, funksionele kapasiteit; dispneevlak, liggaamsamestelling; geneesheer algehele evaluering asook pasiënt algehele evaluering. Die oefenprogram het uit een-uur sessies bestaan, wat drie keer per week vir 12 weke plaasgevind het. Die oefensessies het elemente van aërobiese en weerstandsoefeninge van die boonste en onderste ledemate ingesluit. Funksionele kapasiteit het drasties verbeter ($p < 0.01$), net so ook die geneesheer en pasiënt algehele evaluering ($p < 0.01$ en $p < 0.01$, respektiewelik). Dispneevlakke het ook verbeter ($p < 0.01$). Gesondheidsverwante lewenskwaliteit het marginaal verbeter ($p = 0.03$). Geen beduidende veranderinge is in die longfunksie en liggaamsamestelling gevind nie. Die studie het bevind dat 'n oefenprogram wat uit aërobiese en weerstandsoefening bestaan gesondheidsverwante lewenskwaliteit, funksionele kapasiteit asook dispneevlakke van pasiënte met chroniese obstruktiwe pulmonêre siekte verbeter. Oefening verminder ook die simptome van chroniese obstruktiwe pulmonêre siekte soos waargeneem deur beide die geneesheer en pasiënt. Oefening verander ook nie longfunksie of liggaamsamestelling van pasiënte met chroniese obstruktiwe pulmonêre siekte nie. Oefening tesame met die geskikte mediese behandeling kan voordelig wees vir chronies obstruktiwe pasiënte in Suid-Afrika.

Keywords: KOPS, lewenskwaliteit, funksionele kapasiteit, rehabilitasie, oefening.

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TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION	1
PURPOSE OF THE STUDY	6
OBJECTIVES	6
Primary Objectives	6
Outline of the thesis	7
CHAPTER TWO: LITERATURE REVIEW	8
DEFINITIONS	8
Chronic Obstructive Pulmonary Disease	8
Emphysema	8
Chronic Bronchitis.....	8
HISTORICAL PREVIEW.....	8
PATHOLOGY OF COPD.....	10
Chronic Bronchitis.....	11
Emphysema	12
PATHOPHYSIOLOGY OF COPD	15
RISK FACTORS FOR COPD.....	17
Smoking Habit.....	17
Genetic Factors	20
Ambient Air Pollution	20
Infections.....	21
Tuberculosis	21
Gender, Race and Socio-economic Status.....	22
Occupational Factors.....	23
CLINICAL FEATURES OF COPD	23
Patient History	23
Physical Examination	24
LABORATORY FINDINGS AND DIAGNOSTIC TESTS	26
Pulmonary Function Measurements.....	26
Forced Expiratory Spirometry	26
Lung Volumes.....	28

Arterial Blood Gases.....	29
Other	30
Chest Radiography	30
Computed Tomography	32
Sputum Examination.....	32
FACTORS THAT AFFECT EXERCISE TOLERANCE	33
Dyspnea.....	33
Malnutrition	34
Effects of Hypoxemia and Hypoxia.....	36
Steroid Myopathy	38
Hyperinflation	39
Diaphragmatic Fatigue.....	41
Hypercapnia and Acidosis.....	43
Deconditioning	46
Cardiac Impairment.....	47
PULMONARY REHABILITATION	48
Introduction.....	48
Exercise in Pulmonary Rehabilitation	50
Strength Training	51
Aerobic/ Endurance Exercise.....	56
CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY	60
ETHICAL APPROVAL.....	60
SELECTION OF SUBJECTS	60
Exclusion criteria	61
Inclusion criteria	63
PRE-INTERVENTION PATIENT ASSESSMENT	65
INTERVENTION PROGRAMME	67
SAFETY MEASURES	69
MEASUREMENTS	72
Six-Minute Walk Test (6MWT).....	72
Aim	72
Description.....	72
Reliability and Validity.....	73

St George’s Respiratory Questionnaire (SGRQ)	74
Aim	74
Description.....	74
Reliability and Validity.....	75
Baseline Dyspnea Index (BDI) and Transitional Dyspnea Index (TDI)	75
Aim	75
Description.....	75
Reliability and Validity.....	76
Forced Expiratory Volume in One Second (FEV₁)	77
Aim	77
Description.....	77
Validity and Reliability.....	78
Body Mass Index (BMI)	78
Aim	78
Description.....	79
Reliability and Validity.....	79
Physician Global Evaluation	79
Aim	79
Description.....	79
Validity and Reliability.....	80
Patient Global Evaluation	80
Aim	80
Description.....	81
Validity and Reliability.....	81
POST-INTERVENTION ASSESSMENT	81
DATA ANALYSIS	81
ABSENTEEISMS AND COMPLICATIONS	82

CHAPTER FOUR: DATA ANALYSIS	84
SUBJECTS	84
SUBJECT DEMOGRAPHICS.....	85
RESULTS	86
Six-Minute Walk Test.....	86
Baseline Dyspnea Index and Transitional Dyspnea Index.....	88
St George’s Respiratory Questionnaire.....	89
Forced Expiratory Volume in One Second.....	91
Patient Global Evaluation	93
Physician Global Evaluation.....	94
DISCUSSION	96
CONCLUSION	98
CHAPTER FIVE: CONCLUSIONS	99
RESEARCH CONCLUSION	99
LIMITATIONS.....	101
FUTURE RESEARCH AND RECOMMENDATIONS	103
REFERENCES.....	105
APPENDICES.....	118

LIST OF TABLES

Table	p.
2.1 GOLD Staging Criteria of COPD.....	27
2.2 Classification of BMI.....	35
2.3 Symptoms and Signs of Hypoxia.....	38
4.1 Patient Demographics.....	86
4.2 Results of 6MWT.....	87
4.3 Baseline and transitional dyspnea indices.....	89
4.4 Results of the SGRQ.....	90
4.5 Results of absolute FEV ₁ and percentage of predicted FEV ₁	91
4.6 Results of the patient global evaluation.....	93
4.7 Results of the physician global evaluation.....	95

LIST OF FIGURES

Figure	p
2.1. A Venn Diagram of Chronic Obstructive Pulmonary Disease... ..	11
2.2 Pathophysiology of COPD and cor pulmonale in COPD.....	16
2.3. Graph of survival.....	19
2.4. Flow volume loops during normal and severe airflow obstruction.....	28
2.5. Typical chest X-ray of emphysematous lungs.....	31
4.1. Subjects who dropped out, were ineligible and who completed the intervention programme.....	85
4.2. Graph showing the difference in the mean distance walked by subjects in the 6MWT, pre- and post-intervention.....	88
4.3. The difference in mean scores achieved by subjects on the SGRQ at pre- and post-intervention evaluations.....	90
4.4. The difference in subjects' mean lung function at pre- and post-intervention evaluations.....	92
4.5. The difference in subjects' mean lung function at the pre- compared to the post – intervention evaluation.....	92

4.6	The difference in mean scores on the patient global evaluation at pre- compared to post-intervention evaluations.....	94
4.7	The difference in mean scores on the physician global evaluation at pre-compared to post-intervention evaluations.....	95

LIST OF ABBREVIATIONS

AACVPR	American Association of Cardiovascular and Pulmonary Rehabilitation
ACSM	American College of Sports Medicine
ADL	Activities of Daily Living
AIDS	Acquired Immunodeficiency Syndrome
ATS	American Thoracic Society
BDI	Baseline Dyspnea Index
BMI	Body Mass Index
BP	Blood Pressure
Ca ⁺	Calcium ions
CO ₂	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
CT	Computed Tomography
D _{LCO}	Diffusing Capacity
ECG	Electrocardiogram
EELV	End-expiratory lung volume
ERV	Expiratory Reserve Volume
FEV ₁	Forced Expiratory Volume in one Second
FEV ₀₋₂₅	Forced Expiratory Volume in the first quarter of forced vital capacity
FEV ₂₅₋₇₅	Forced Expiratory Volume in the middle half of FVC
FRC	Functional Residual Capacity
FVC	Forced Vital Capacity
GOLD	Global Initiative for Chronic Obstructive Pulmonary Disease
HBPM	Heart Beats Per Minute
HIV	Human Immunodeficiency Virus

HRQL	Health-related Quality of Life
H ⁺	Hydrogen ions
IC	Inspiratory Capacity
IRV	Inspiratory Reserve Volume
LV	Left Ventricle (left ventricular)
MRC	Medical Research Council
OBLA	Onset of Blood Lactate Accumulation
O ₂	Oxygen
PCO ₂	Partial Pressure of Carbon Dioxide
PEF	Peak Expiratory Flow
PO ₂	Partial Pressure of Oxygen
QOL	Quality Of Life
Q _T	Cardiac Output
RPB	Rate of Perceived Breathlessness
RPE	Rate of Perceived Exertion
R _{aw}	Airways resistance
RV	Residual Volume
S _a O ₂	Percent saturation of arterial oxygen
SGRQ	St George's Respiratory Questionnaire
SVC	Slow Vital Capacity
TB	Tuberculosis
TDI	Transitional Dyspnea Index
TLC	Total Lung Capacity
V _E	Expired ventilation per minute
VO ₂	Volume of Oxygen consumed per minute
VO ₂ max.	Maximal Oxygen uptake

V/Q	Ventilation Perfusion
V _r	Volume of air in the lungs at rest
V _T	Tidal Volume
WHO	World Health Organisation
6MWT	Six-Minute Walk Test for Distance

CHAPTER ONE: INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a major cause of chronic morbidity and mortality throughout the world (Curtis, Deyo & Hudson, 1994:162; Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD), 2001a; Pauwels *et al.*, 2001:1257; Lundback *et al.*, 2003:115; Barnes, 2003:87). In 1990 COPD was the sixth leading cause of death in the world, responsible for more than two million or 4% of deaths (Lundback *et al.*, 2003: 115). By 2020 COPD will be the fourth leading cause of death worldwide being superseded only by heart disease, cerebrovascular disease and cancer (GOLD, 2003). COPD will share fourth place with Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome (AIDS) (GOLD, 2002). Whereas the first three conditions are declining in prevalence, COPD is on the increase and will maintain this trend until 2020 (GOLD, 2001a). “By 2020, the mortality is expected to increase to 4-5 million, or 7% of all deaths” (Lundback *et al.*, 2003:115). “According to the statistics produced by the American Lung Association, 15 million Americans suffer from COPD and it claimed the lives of 87, 000 Americans in 1992” (Mak, n.d). In the United Kingdom it is estimated that 18% of males and 14% of females aged 40-68 years have developed features of COPD, and in the USA, 13,6% of males and 11,8% of females aged 65-74 years are thought to have COPD (Mak, n.d.). The prevalence of COPD is extremely high but it is thought that the figures are distorted and reflect far lower totals than those, which are actually true (Lundback *et al.*, 2003:115-116). “The substantial increase in the global burden of COPD projected over the next 20 years reflects, in large part, the increasing use of tobacco worldwide, and the changing age structure of populations in developing countries” (GOLD, 2001b). National figures for South Africa do not exist but a high prevalence of risk factors such as tuberculosis (TB), childhood lung disease and “particularly a high smoking prevalence of 24% in our population could make our country a Mecca for COPD” (GOLD, 2002)

Tobacco smoking carries the highest risk for COPD. Fifty percent (50%) of all smokers develop COPD (Lundback *et al.*, 2003:119), and 75% of deaths from chronic bronchitis and emphysema are attributable to tobacco smoking (World Health Organization (WHO),

1999:66). The WHO estimates that about 500 million people today will eventually be killed by tobacco smoke (WHO, 1999:65). On current smoking patterns, the WHO estimates that by the third decade of the 21st century, smoking is expected to kill 10 million people annually worldwide – more than the total deaths from malaria, maternal and major childhood conditions, and tuberculosis combined (WHO, 1999:67). Not only are smokers affected, but also exposure to other people's smoking is associated with a somewhat higher risk of lung cancer, amongst several other important ailments (WHO, 1999:66). Consequently the economic burden of tobacco smoking is enormous. Tobacco industries may derive great economic benefits, "however, economic analyses conclude that even with highly conservative assumptions, the economic costs of tobacco exceed its estimated benefits" (WHO, 1999: 68). An analysis which estimated the additional costs (in mortality and health care) and the benefits (to consumers and producers) per year if global tobacco production were to increase by 1000 metric tons, concluded that there would be net economic losses of 13,6 million dollars per year (WHO, 1999:68).

"Because COPD is highly prevalent and can be severely disabling, direct medical expenditures and the indirect costs of morbidity and premature mortality from COPD can represent a substantial economic and social burden for societies and public and private insurance payers worldwide." (GOLD, 2001b)

"By the year 2020, COPD will be fifth among the conditions that will be the highest burden to society on a worldwide scale" (Hurd, 2000:1S). As COPD progresses and culminates in severe, prolonged disability (Fishman, 1998:684), it becomes "responsible for a significant part of physician visits, emergency department visits, and hospitalisations" (Pauwels *et al.*, 2001: 1259). Hospital admission or readmission for an exacerbation of COPD often signals the beginning of the terminal phase of the illness (Morgan, 2003:95). Not only is this bad news for the patient but also "for the health services it is a significant component of the cost of care for a condition that is increasingly burdensome" (Morgan, 2003:95). In 1993, the United States estimated an annual expenditure of 23,9 billion dollars as a result of COPD, including 14,7 billion dollars in direct expenditures for medical care services, 4,7 billion dollars in indirect morbidity costs, and 4,5 billion dollars in indirect costs related to premature mortality (GOLD, 2001b). "In 1996, lost work productivity, disability, and premature

mortality from COPD in the UK accounted for an estimated 24 million days of work lost” (GOLD, 2001b). In developed countries the direct medical costs are substantial as a result of the high prevalence and morbidity of COPD (GOLD, 2001b). But “in developing countries, the indirect cost of COPD from loss of work and productivity may be more important than the direct costs of medical care” (GOLD, 2001b). In South Africa, pulmonary disorders are one of the three main causes of disability and are increasing annually in terms of days off work and monetary value of claim payouts” (Schorn, 2001:2).

The progressive airflow obstruction that occurs with COPD leads to permanent disability and impaired mood state, especially with increasing severity of COPD (Wedzicha *et al.*, 1998:363). Several studies have shown that COPD leads to an impaired quality of life (Wijkstra *et al.*, 1994:269). Improved survival time is always an important aim of treatment but due to the irreversible and progressive nature of COPD, it has now become a far more important goal, for most patients, to improve their quality of life (QOL) (Curtis *et al.*, 1994:162). The St George’s Respiratory Questionnaire (SGRQ) is one of the most popular measures of health-related quality of life (HRQL) (Jones *et al.*, 1992:1326). The SGRQ is an accurate measure of the impact of COPD on a patient’s daily life and well-being. The three angles of the SGRQ measure the symptoms (frequency and severity), activities (activities that cause or are limited by breathlessness) and impacts (social functioning, psychological disturbances resulting from COPD) (American Thoracic Society (ATS), 2002b:no page number).

Functional exercise intolerance is a common manifestation of patients with COPD (Maltais *et al.*, 1996:288), mainly due to breathlessness on exertion (Strijbos *et al.*, 1996:366). “Breathlessness” or “shortness of breath”, referred to as dyspnea in COPD, is experienced as a discomfort during breathing at a level of activity that is not expected. As a result of dyspnea, COPD patients develop a lack of confidence regarding their ability to avoid breathlessness while engaging in activities of daily living, even though they are physically capable of performing them (Scherer & Schneider, 1997:16). “Patients with respiratory disorders volitionally stop exercise when they are no longer willing to tolerate the intensity of

the accompanying symptoms” (Hamilton *et al.*, 1995:2021). As COPD progresses, the patient adopts a breathing pattern (usually fast and shallow) that is detrimental to gas exchange, which may in turn worsen their symptoms (Celli, 1995:861). The progressive deconditioning associated with inactivity initiates a vicious cycle with increased dyspnea at lower activity demands.

“Current therapies are not very effective, and no current treatment prevents the relentless progression of airflow limitation that characterizes this disease” (Barnes, 2003:87). “Medical treatment has only partial success in alleviating symptoms and improving functional capacity (Calverley and Pride, 1995:528). Pulmonary rehabilitation, as an addition to medical therapy, has had tremendous success in enhancing the health of COPD patients beyond medication alone. Although pulmonary rehabilitation does not improve lung function (A Statement of the ATS and European Respiratory Society, 1999:S2), it has demonstrated many other positive outcomes. Pulmonary rehabilitation improves QOL in COPD patients by minimising their symptoms and improving their ability to function in activities of daily living (ADL) (Curtis *et al.*, 1994: 162; Celli, 1995: 864; American Association of Cardiovascular and Pulmonary Rehabilitation (ACVPR), 1998:3; Fishman, 1998:714). Pulmonary rehabilitation reduces hospitalisations and use of medical resources (ACVPR, 1998: 3). Studies suggest that pulmonary rehabilitation can reduce hospital days in patients by 38% in the year following pulmonary rehabilitation (Celli, 1995:861; Fishman, 1998:715). Reduced respiratory symptoms (dyspnea) are experienced after pulmonary rehabilitation (Celli, 1995: 864; ACVPR, 1998: 3; Fishman, 1998:714). COPD patients experience improved psychosocial symptoms, for example a reversal of anxiety and depression and improved self-efficacy, after participation in pulmonary rehabilitation (Celli, 1995: 864; ACVPR, 1998:3; Fishman, 1998:714). Pulmonary rehabilitation increases exercise tolerance and performance amongst COPD patients (Celli, 1995: 864; ACVPR, 1998:3; Fishman, 1998:714; A Statement of the ATS and European Respiratory Society, 1999:S2). Increased survival time is experienced in some patients and some patients are even able to return to work (ACVPR, 1998:3; Fishman, 1998:714).

Pulmonary rehabilitation, a well-researched topic in westernized countries, has repeatedly been successful. However, there has been no research published in reviewed journals with regards to pulmonary rehabilitation in South Africa and/or other developing countries. It is reported that the prevalence of COPD is set to increase substantially with the export of tobacco to developing countries such as India, Mexico, Cuba, Egypt, South Africa and China (Lomas, 2002:735). These populations are subject to a number of other risk factors that are likely to increase their chances of developing COPD, for example the high correlation between socioeconomic class and COPD (ATS, 1995:S79; Pauwels *et al.*, 2001:1260; Viegi *et al.*, 2001:4); crowding; poor nutrition and other factors relating to lower socioeconomic populations (Pauwels *et al.*, 2001:1260). It has also been found that poorer people tend to smoke more than affluent people (WHO, 1999:68). The general population of developing countries is not likely to have extensive medical insurance and thus they are less likely to receive the complete medical attention that is often needed; this is reflected in the higher morbidity and mortality rates of lower socioeconomic classes (ATS, 1995:S79; Pauwels *et al.*, 2001:1260). Pulmonary rehabilitation has proved to reduce health care expenses with a “reduction in the utilization of other health care resources such as visits to the emergency department or a physicians office and phone calls to the physicians office” (ATS, 1999:1669) as well as reduced time spent in hospital (Morgan, 2003:96). If pulmonary rehabilitation is successful in South Africa it has the potential to decrease the ill afforded medical burden that COPD has on a developing country of many low-income groups.

Pulmonary rehabilitation is a broad term that incorporates many components. Exercise, however, is the single most important component of pulmonary rehabilitation (Celli, 2003). COPD patients who adhere to prescribed exercise programmes are likely to become more actively involved in their own healthcare, more independent in performing daily activities, and less dependent on others, including health professionals (Ries *et al.*, 1995:823). Exercise training as a part of pulmonary rehabilitation has been well documented however. On review of the literature, it appears that there is not complete consensus on the type, the intensity or duration of exercises in order to achieve optimal benefits. According to Maltais *et al.*, (1997:555) there is still no consensus about the optimal training strategy and the mechanisms of improvement. A review of randomised trials by the ACCP/AACVPR Pulmonary

Rehabilitation Guidelines Panel (1997:1368) also failed to “yield firm recommendations on optimal specific training regimens for patients with COPD”. Although the principles of training for healthy persons or for cardiac patients have been well studied, these principles do not necessarily apply to patients with COPD (Hodgkin, Connors & Bell, 1993:90). Maltais *et al.*, (1997:556) suggest that "precise quantification of the amount of training actually performed would be extremely useful in comparing results from different studies, and would facilitate the definition of optimal training intensity and duration for COPD patients".

This study therefore aimed to quantify the precise intensity, type and duration of exercise that accomplishes significant improvements in HRQL and functional capacity. The aim of the study was to achieve this within a South African context and pave the way for future studies to improve the availability of successful, cost reducing, health care resources within a country where no such research study has been published.

PURPOSE OF THE STUDY

The purpose of this study was to determine whether participation in a 12-week exercise programme had an effect on the health-related quality of life (HRQL), functional status, forced expiratory lung function, dyspnea index and body mass index (BMI) of an identified population of COPD patients.

OBJECTIVES

Primary Objectives

To investigate whether exercise has a significant effect on the following variables after a 12-week intervention programme:

- Six-Minute Walk Test for distance (6MWT)

- St George's Respiratory Questionnaire (SGRQ)
- Baseline Dyspnea Index (BDI) and Transitional Dyspnea Index (TDI)
- Patient global evaluation
- Physician global evaluation

OUTLINE OF THE THESIS

Chapter two is a review of the literature regarding COPD and pulmonary rehabilitation in the form of exercise. The second chapter also explains how exercise potentially benefits patients with COPD. The research design and methodology are covered in chapter three with details of all the variables used, pre- and post-intervention evaluations and the selection of patients. Chapter four displays the data captured in the form of graphs and it explains the results that were gathered. Chapter five concludes the thesis with suggestions of possible improvements to the study design as well as future scope for such research.

CHAPTER TWO: LITERATURE REVIEW

DEFINITIONS

Chronic Obstructive Pulmonary Disease

“COPD is a disease state that is characterized by airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response of the lungs to noxious gases” (Pauwels *et al.*, 2001:1256).

Emphysema

The American Thoracic Society (1995:S78) defines emphysema as:

“An abnormal permanent enlargement of the airspaces distal to the terminal bronchioles, accompanied by destruction of their walls and without obvious fibrosis. *Destruction* is defined as lack of uniformity in the pattern of respiratory airspace enlargement; the orderly appearance of the acinus and its components is disturbed and may be lost.”

Chronic Bronchitis

The presence of a chronic productive cough for three months in each of two successive years in a patient in whom other causes of cough have been excluded (ATS, 1995:S78).

HISTORICAL PREVIEW

“The occurrence of diseases characterized by cough, expectoration, wheezing, and dyspnea, first on exercise, and later at rest has been known at least since the time of Hippocrates” (Calverley and Pride, 1995:3). According to Calverley and Pride (1995:3) Floyer gave the first clear description of asthma in the early 18th century. Throughout the 19th century the

word 'asthma' was used synonymously with dyspnea. In the eighteenth century Laenic began attempts to classify patients with obstructive airway diseases. "Laenic used the term pulmonary or bronchial catarrh from the Greek word meaning 'to flow down' for excessive production of bronchopulmonary secretion" (Calverley and Pride, 1995:3). Laenic defined emphysema as we know it today and in 1808 Charles Badham introduced the term bronchitis into medicine.

During the mid-20th century many studies were undertaken to determine the nature, frequency and causes of COPD (Calverley and Pride, 1995:3). In 1958 a Ciba Foundation Guest Symposium was held and subsequently the first attempt to achieve consensus on the definitions of disorders associated with COPD was published (Calverley and Pride, 1995:10). Senior and Anthonisen (1998:S139) suggest that it was only in the 1960s that plausible ideas about the pathogenesis of COPD appeared, when researchers in Sweden and the United States made discoveries that have become the "cornerstone of current thinking. One was discovering [α_1 -antitrypsin] deficiency and its association with emphysema. The other was the finding that lesions resembling human emphysema could be induced with proteolytic enzymes in experimental animals". In 1962 the ATS gave similar descriptions of COPD to those of the Ciba Symposium. In a historical review of COPD by Bone *et al.* (1997:G3-1), the ATS described COPD as a "disease of chronic diffuse irreversible airflow obstruction" (Bone *et al.*, 1997:G3-1). Subcategories included chronic bronchitis, emphysema and asthma. These three were included as subcategories of COPD because they were "defined pathophysiologically and the clinical and physiologic manifestations of these three diseases overlapped" (Bone *et al.*, 1997:G3-1). According to the ATS (1995:S78) it has since become more practical to separate COPD from asthma. COPD and asthma have different causes, clinical courses, and responses to therapy (ATS, 1995:S78). In 1987 the ATS made an official statement distinguishing COPD from asthma (Bone *et al.*, 1997:G3-1). In Bone *et al.*, (1997:G3-1) the ATS defined COPD as "a disorder characterized by abnormal tests of expiratory flow over periods of several months of observation". The three subcategories of COPD were defined as chronic bronchitis, emphysema and peripheral airway disease (Bone *et al.*, 1997:G3-1).

PATHOLOGY OF COPD

COPD is characterised by progressive airflow limitation (Albert, Spiro & Jett, 1999:7.37.1) that is not fully reversible (Barnes, 2000:269). “COPD encompasses disease conditions that vary from chronic bronchitis, with obstruction of the airways, to emphysema, characterised by enlargement of air spaces; destruction of lung parenchyma; loss of lung elasticity; and closure of the airways” (Wouters, 2002:1067).

Most COPD patients have both pathologic conditions (chronic obstructive bronchitis and emphysema) but the extent of emphysema and chronic bronchitis in each patient varies (Barnes, 2000:269). In the past asthma was subsumed under COPD but more recently these conditions have been separated (ATS, 1995: S78). The airway obstruction in many patients with COPD may include significant reversible components and some patients with asthma may go on to develop irreversible airflow obstruction indistinguishable from COPD (ATS, 1995:S78) – particularly if they are smokers. *Figure 2.1* (p11) illustrates the relationship between chronic bronchitis, emphysema, asthma, and airflow obstruction.

The Venn diagram below (*Figure 2.1*) illustrates non-proportionally the subsets of patients with chronic bronchitis, emphysema and asthma. The shaded subsets three, four, five, six, seven and eight are those of COPD. Asthma is defined by a reversible airflow obstruction. Subset nine shows patients with asthma whose airflow is completely reversible. In some cases of asthma the airflow obstruction is not entirely reversible and it becomes impossible to differentiate patients with asthma from patients with emphysema or chronic bronchitis who have partially reversible airflow obstruction with airway hyperreactivity. Patients with irreversible asthma are classified as COPD, these are shown as subsets six, seven and eight. Chronic bronchitis and emphysema with airflow obstruction usually occur together (shown in subset five) while the patients of subset eight may have asthma associated with both chronic bronchitis and emphysema. An asthmatic patient who is exposed to chronic irritation of the airways, from cigarette smoke, for example, may develop a chronic productive cough – a symptom of chronic bronchitis (subset six). Patients who have chronic bronchitis and/or

emphysema without airflow obstruction are not classified as having COPD, as in subsets one, two and 11. Subset 10 is the group of patients with airway obstruction due to diseases such as cystic fibrosis or obliterative bronchiolitis (ATS, 1995:S78).

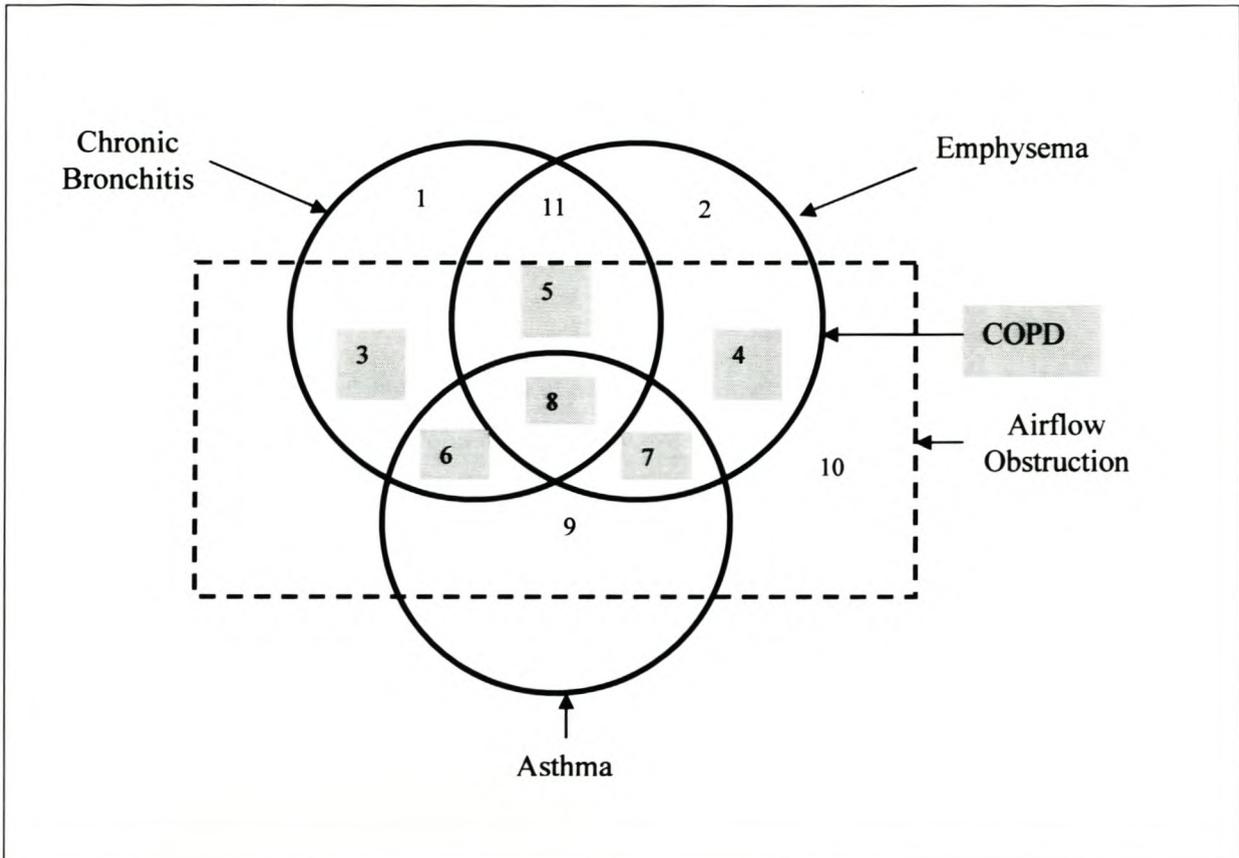


Figure 2.1. A Venn Diagram of Chronic Obstructive Pulmonary Disease (ATS, 1995:S78).

Chronic Bronchitis

Chronic bronchitis is the presence of a productive cough of more than three months for more than two successive years (Barnes, 2000:269). Chronic bronchitis is generally characterized by a chronic cough with excessive production of sputum (American College of Sports Medicine (ACSM), 1998:315). A number of morphologic changes in the airways occur with chronic bronchitis. According to Barnes (2000:269) the cough is due to:

“hypersecretion of mucus and is not necessarily accompanied by airflow limitation. However, there is some epidemiologic evidence that mucus hypersecretion is accompanied by airflow obstruction, perhaps as a result of obstruction of peripheral airways.”

The chronic hypersecretion of mucus results from an increase in the number and size of goblet cells in the bronchi and bronchioles as well as the enlargement of submucosal glands in the proximal airways (McAllister, 2002a:41). “The submucosal glands reveal dilated ducts...and hyperplasia of their glandular elements” (Murray *et al.*, 2000b:1203). The marked increase in submucosal glands is largely as a consequence of cigarette smoking as well as other irritants that may be involved (Calverly and Pride, 1995:13). Submucosal gland enlargement is non-specific to chronic bronchitis, similar changes also occur in other diseases, such as cystic fibrosis (ATS, 1995:S81).

“Membranous airways of less than 2 mm in diameter, the [terminal] bronchioles [and alveolar ducts], show varying degrees of plugging with mucus, goblet cell metaplasia, inflammation, increased smooth muscle, and distortion due to fibrosis and loss of alveolar attachments” (Murray *et al.*, 2000b:1203). Focal squamous metaplasia and hypertrophy of airway smooth muscle may be present. Squamous metaplasia is mostly induced by smoking.

Chronic bronchitis is known for the development of bronchoscopically visible diverticula in the airways and the colonization of normally sterile airways with bacteria, often *Streptococcus pneumoniae* and *Haemophilus influenzae* (George *et al.*, 1990:174).

Emphysema

Emphysema is technically a disease of the lung parenchyma secondarily affecting small airways (ACSM, 1998:317). “The pathology includes abnormal permanent enlargement of airspaces accompanied by destruction of alveolar walls. The biochemical basis of the disease is an imbalance in the protease versus anti-protease equilibrium” (ACSM, 1998:317; Senior and Anthonisen, 1998:S139). The “protease-antiprotease hypothesis has prevailed as a central theme for nearly 40 years” (Hogg and Senior, 2002:832). The hypothesis states that alveolar

destruction in emphysema occurs when “the balance between lung matrix breakdown and defenses against lung breakdown is tipped in favor of destruction” (Hogg and Senior, 2002:832). “Proteases promote degradation of elastin and anti-proteases inhibit degradation” (ACSM, 1998:317), the major threat being neutrophil derived elastase (a normal component of neutrophil granules) (George *et al.*, 1990:177). Elastin forms a large component of connective tissue in the alveolar wall. Destruction of this lung tissue results either from increased protease activity or a deficiency of anti-protease activity (ACSM, 1998:317). “Smokers demonstrate significantly increased pulmonary proteolytic activities, possibly related to accumulation of inflammatory cells (neutrophils, macrophages) containing high concentrates of protease enzymes” (ACSM, 1995:317). Smoking is by far the most important risk factor of COPD although of comparable importance is alpha₁-antitrypsin deficiency (Albert *et al.*, 1999:7.37.2) – a potent anti-protease (ACSM, 1998:317). Those with a genetic alpha₁-antitrypsin deficiency are prone to develop severe emphysema at a young age even in the absence of a smoking history (ACSM, 1998:317).

“The hallmark of emphysema is a loss of lung elasticity and reduction of elastic recoil pressure due to accelerated alveolar destruction. Small airways lose radial traction to the surrounding alveolar walls and become easily collapsible during exhalation because intra-thoracic pressure becomes more positive. Patients with emphysema can expel a larger volume during a slow exhalation than during a maximal force exhalation because intra-thoracic pressure is less positive and airway compression is minimized during a slow exhalation.” (ACSM, 1998:317)

The distribution of airflow limitation is not uniform so the distribution of ventilation is heterogenous and similarly the distribution of perfusion as the “emphysematous destruction of the terminal lung units includes destruction of the corresponding alveolar capillaries” (Albert *et al.*, 1999:7.37.3). Some ventilation reaches lung units containing no capillaries and dead space is increased (ACSM, 1998:317). Emphysematous lungs often develop bullae. Bullae are the emphysematous spaces with a diameter of more than one centimetre in the fully distended state (Aubry, Wright & Myers, 2000:11). “This physiological pattern is distinct from that seen in chronic bronchitis” (ACSM, 1998:317).

Three types of emphysema can be distinguished. The first type, centriacinar or centrilobular emphysema, begins in the respiratory bronchioles and spreads peripherally (ATS, 1995:S81). “Fenestrations develop in the airway walls, enlarge, become confluent, and form a single space as the walls disintegrate. Initially, the most distal alveolar ducts and sacs and the alveoli are preserved” (Bone *et al.*, 1997:G3-4). Centriacinar emphysema can cause bullous emphysema when numerous spaces enlarge to a diameter of more than one centimetre (Aubry *et al.*, 2000:13). Centrilobular emphysema is a form of emphysema associated with longstanding cigarette smoking (ATS, 1995:S81). Centrilobular emphysema predominantly involves the upper half of the lungs and is prevalent in males (Bone *et al.*, 1997:G3-4). Focal emphysema is the form of centriacinar emphysema that occurs in coal worker’s pneumoconiosis (ATS, 1995:S81).

The second type is panacinar emphysema. Panacinar emphysema “involves the entire acinis, progressing from early diffuse destruction, in which the distinction between alveolar ducts and alveoli is lost, to total effacement of the alveolus, with only strands of lung tissue remaining” (George *et al.*, 1990:176), which are usually blood vessels (Bone *et al.*, 1997:G3-4). Panalobular emphysema is characteristically uniformly distributed throughout the lung, although the basal areas of the lung tend to be most affected (Bone *et al.*, 1997:G3-4). Focal panacinar emphysema at the lung bases may accompany centrilobular emphysema in smokers.

The third type, distal acinar emphysema, also known as paraseptal emphysema, preferentially involves distal airway structures, alveolar ducts, and sacs (ATS, 1995:S81). This form of emphysema is thought to be a major cause of spontaneous pneumothorax (Bone *et al.*, 1997:G3-4). With this form of emphysema, airflow is frequently well preserved (ATS, 1995:S81). A large amount of overlap exists between the three types of emphysema to the extent that the clinical diagnoses of pure centrilobular or panacinar emphysema requires the use of expensive technology (i.e. computed tomography).

PATHOPHYSIOLOGY OF COPD

Pathological changes in the lungs lead to physiological changes characteristic of COPD (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b). Pathological changes include and usually occur in this order over the course of the disease: mucus hypersecretion, ciliary dysfunction, airflow limitation, pulmonary hyperinflation, gas exchange abnormalities, pulmonary hypertension and cor pulmonale (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b). Mucus hypersecretion and ciliary dysfunction cause a chronic cough and the production of sputum, these two symptoms are often present for many years before the development of other symptoms or physiologic abnormalities occur (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b).

“Expiratory airflow limitation, best measured through spirometry, is the hallmark physiologic change of COPD and the key to the diagnoses of the disease” (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b). This is largely as a result of airway obstruction and the consequent increase in airway resistance and to a lesser extent the destruction of alveolar attachments, which inhibits the ability of the small airways to maintain patency (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b).

In the advanced stages of COPD, peripheral airways obstruction and parenchymal vascular abnormalities reduce the lung's capacity for gas exchange resulting in hypoxemia and, later on, hypercapnia (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b). Pulmonary hypertension is a frequent and major cardiovascular complication which develops late in the natural history of COPD (Stage III: Severe COPD) (Pauwels *et al.*, 2001: 1258-1259; GOLD, 2001b). Pulmonary hypertension is associated with the development of cor pulmonale, shorter survival rates and frequent use of health resources (Barbera, Peinado & Santos, 2003:892). *Figure 2.2* illustrates the pathophysiology of COPD and cor pulmonale in COPD (adapted from Pierson, 2000:47; Pauwels *et al.*, 2001:1259).

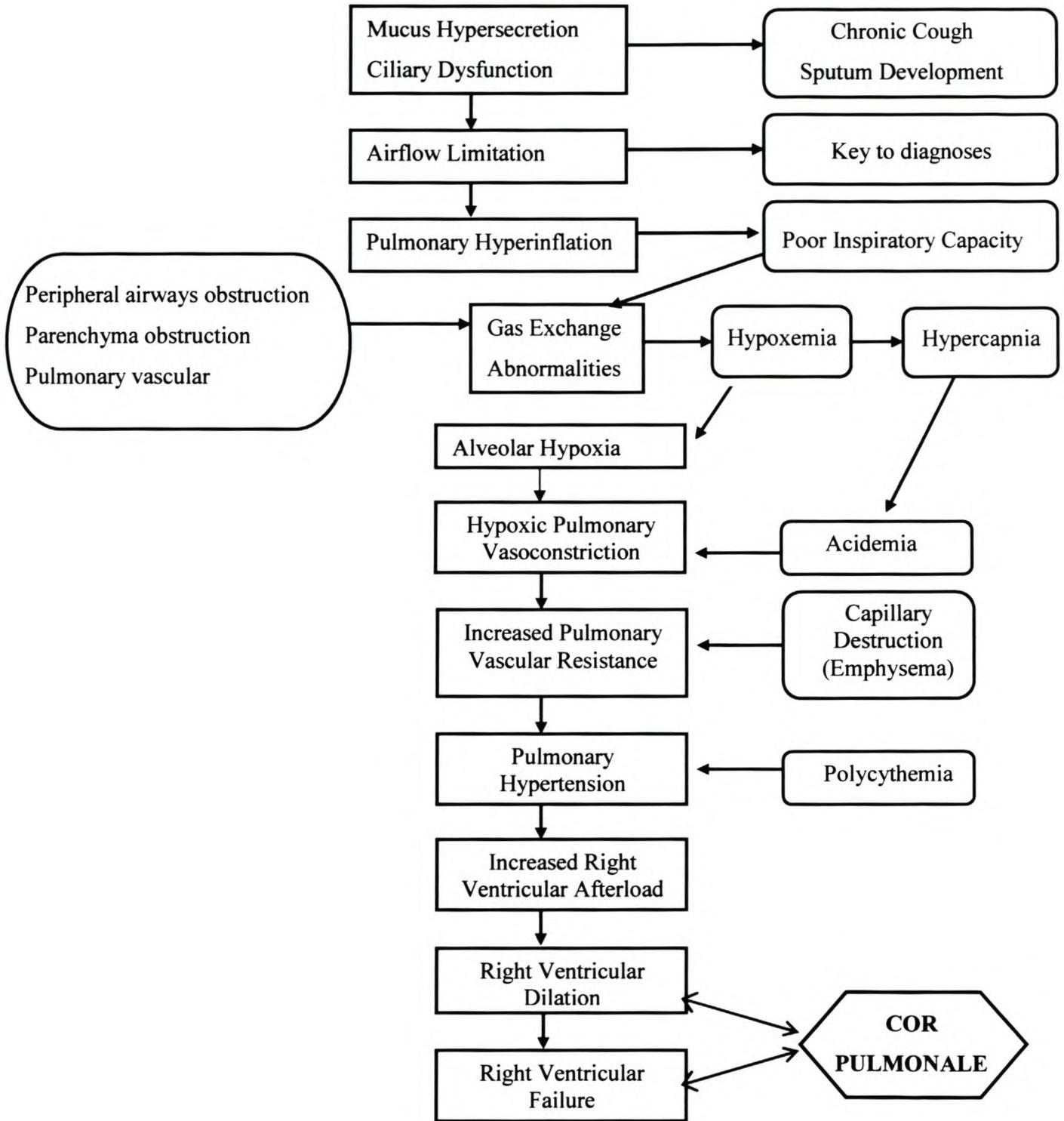


Figure 2.2. Pathophysiology of COPD and cor pulmonale in COPD (adapted from Pierson, 2000:47; Pauwels *et al.*, 2001:1259).

RISK FACTORS FOR COPD

The following are risk factors for COPD: smoking habit; passive smoking; ambient air pollution; alpha₁-antitrypsin deficiency; airway and allergy hyperresponsiveness; childhood infections; low birth weight; gender; race; socioeconomic status; tuberculosis (TB); and occupational factors (ATS, 1995:S79; Fishman, 1998:662). The primary risk factor of COPD is unquestionably tobacco smoking (ATS, 1995:S79; Senior and Anthonisen, 1998:141), with alpha₁-antitrypsin (a genetic factor) being the second most important risk (Fishman, 1998:662). The most common risk factors are elaborated in more detail.

Smoking Habit

“Since about 1950, more than 70 000 scientific articles have left no scientific doubt that prolonged smoking is an important cause of premature mortality and disability worldwide. Estimates suggest that in developed countries, smoking will have caused about 62 million deaths between 1950 and 2000. The WHO now estimates that smoking causes about four million deaths annually worldwide.” (WHO, 1999)

A study by Lundback *et al.*, (2003:118) found that as many as 50% of smokers may develop COPD, not the 10-15% proposed in past literature (Scanlon *et al.*, 2000:382; Barnes, 2003:88). COPD patients who smoke have a higher mortality rate, they also have a higher prevalence of lung-function abnormalities, respiratory symptoms and all forms of COPD (ATS, 1997:S79). “Pipe and cigar smokers have a higher morbidity and mortality rates for COPD than nonsmokers, although their rates are lower than those for cigarette smokers” (ATS, 1995:S79). The Lung Health Study by Senior and Anthonisen (1998:S141) found that airways reactivity was greater in women than in men smokers, and forced expiratory volume (FEV₁) may decline more rapidly in women when allowances are made for lung size and degree of smoking. Lomas (2002:735) also states that COPD is becoming more prevalent among “western women and is set to increase substantially with the export of tobacco to developing countries such as India, Mexico, Cuba, Egypt, South Africa and China”.

Fletcher and colleagues (1976) concluded in their study that tobacco smoke is the direct cause of lung damage of COPD. Not all smokers develop clinically significant COPD, suggesting that genetic factors modify each person's risk (Pauwels *et al.*, 2001:1260) although the genetic contribution to COPD is poorly understood (Scanlon *et al.*, 2000:382). The ATS (1997:S79) states that mortality in COPD patients can be predicted by the age the patient started smoking, total pack years (pack years are the number of years the patient has smoked, multiplied by the number of cigarettes smoked per day divided by 20] and current smoking status. Factors that contribute to the development of COPD include heavy tobacco smoking, long duration of smoking and smoking of high tar cigarettes (Scanlon *et al.*, 2000:382). On average, a cigarette smoker's rate of expiratory airflow decreases twice as fast (40 ml a year) compared to that of non-smokers (20 ml a year) (Fishman, 1998: 699). However, to a certain extent, the cessation of smoking can halt the progression of COPD (Wise, 1997:418). According to Hodgkin *et al.*, (1993:120), "if cigarette abstinence occurs early enough, COPD patients with mild dysfunction may delay or perhaps eliminate their predicted encounter with severe pulmonary impairment". Baum and Wolinsky (1994:1004) go so far to say that if cigarette smoking were to cease, COPD would disappear as an important health problem. "Hence, the most direct approach to reduce the risk of COPD is to reduce cigarette smoking" (Scanlon *et al.*, 2000:382). *Figure 2.3* is a graph that shows the decline in lung function of smokers, non-smokers and smokers who quit smoking (Davies, n.d.).

A number of interacting mechanisms appear to be operating in the pathogenesis of COPD caused by cigarette smoking. According to Fishman (1998:699), emphysema develops from lung damage, "which can be caused by either direct injury inflicted by cigarette smoke – reduced oxidants or by inflammatory mediators recruited into the lung as a consequence of exposure to smoke". Chronic bronchitis appears to develop from similar mechanisms in the airways (Fishman, 1998:699).

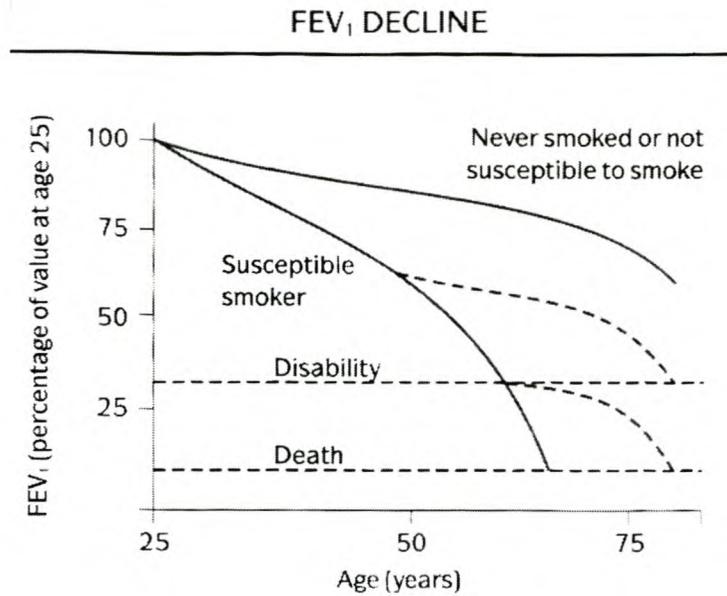


Figure 2.3 Graph of Survival (Davies, n.d.)

“Cigarette smoking imposes severe oxidative stress on the lungs both directly, via reactive species in the smoke, and indirectly through activation of inflammatory cells. Oxidative stress may contribute to COPD through many biological actions, including cellular injury, oxidation and nitration of proteins, changes in gene expression, stimulation of mucous secretion, inactivation of antiproteases, expression of proinflammatory mediators, remodeling of blood vessels, and enhancement of apoptosis. Markers of oxidative stress (e.g., hydrogen peroxide, 8-isoprostane, and lipid peroxides) are elevated in the breath or serum of subjects with COPD, and epidemiological studies have demonstrated negative associations of dietary antioxidant intake with pulmonary function and with obstructive airway disease.” (Croxtton *et al.*, 2002:841)

“Passive exposure to cigarette smoke may also contribute to respiratory symptoms and COPD by increasing the lung’s total burden of inhaled particulates and gases” (Pauwels *et al.*, 2001:1260). Passive smoking is also referred to as environmental tobacco smoke or “second-hand smoke” by the ATS (1995:S79). According to the ATS (1995:S79), children whose parents smoke have a higher prevalence of respiratory disorders and appear to have deficiencies in tests of pulmonary function when compared to children with non-smoking parents. Smoking during pregnancy is also thought to “pose a risk for the fetus, by affecting

lung growth and development *in utero* and possible priming of the immune system” (Pauwels *et al.*, 2001:1260). The ATS (1995:S79) suggests that all children should be protected from exposure to tobacco smoke.

Genetic Factors

Genetic factors are important in determining a person’s predisposition to the development of emphysema (Barnes and Godfrey, 1997:3). According to Fishman (1998:662), the strongest genetic risk is the deficiency of alpha₁-antitrypsin. Although in the United States a genetic deficiency of alpha₁-antitrypsin accounts for less than 1% of COPD (ATS, 1995:S79). Alpha₁-antitrypsin (also known as alpha₁-protease inhibitor) is a serum protein produced by the liver and normally found in the lungs. Its main role is the inhibition of neutrophil elastase (ATS, 1995:S79). A deficiency in alpha₁-antitrypsin results in the destruction of elastin by the neutrophil elastase and a tendency to develop severe emphysema at a young age even in the absence of a smoking history (ACSM, 1998:317). Although even with smoking and alpha₁-antitrypsin deficiency (the two highest risk factors), it is still not possible to predict who will actually develop COPD (Fishman, 1998:662).

Ambient Air Pollution

Exposure to air pollution, particularly sulphur dioxide and particulates (black smoke), is associated with an increased prevalence of chronic bronchitis and COPD (Barnes and Godfrey, 1997:3). A difference is noted between the death rates of urban compared to rural dwellers with COPD (Fishman 1998: 662). However, the role of air pollution in the aetiology of COPD is thought to be fractional compared to the role of cigarette smoking (ATS, 1995:S79; Pauwels *et al.*, 2001:1260). There has also been an association of lung deficiencies with indoor nitrogen dioxide levels and damp housing (ATS, 1995:S79). The ATS (1995:S79) also suggests that “the use of solid fuels for cooking and heating without adequate ventilation” may result in “high levels of indoor air pollution and account for the development of COPD”.

Infections

“Chest infection during the first year of life is associated with COPD in later life” although there is “little evidence that subsequent chest infections are important in this regard” (Barnes and Godfrey, 1997:3). More recent studies concluded that bacterial colonisation is actually an important factor relating to the decline of lung function in COPD patients, and that rising airway bacterial load and a change in bacterial species are associated with greater airway inflammation and accelerated decline in lung function (Wilkinson *et al.*, 2002:1095). According to Pauwels *et al.*, (2001:1260) it is a history of severe childhood respiratory infections that is associated with “reduced lung function and increased respiratory symptoms in adulthood”. Although Pauwels *et al.*, (2001:1260) state that the viral infections may be related to other factors, for example, low birth weight (also known to presage “low FEV₁ and high COPD mortality in later life”) (Fishman, 1998:662).

Tuberculosis

“Tuberculosis (TB) is a contagious, potentially fatal infection caused by the airborne bacterium *Mycobacterium tuberculosis*, *M. bovis*, or *M. africanum*” (Stead, 2000:no page number). A person infected with TB has a five percent chance of developing an active infection within one to two years (Stead, 2000:no page number). A person infected with AIDS who becomes infected with TB has a 50% chance of developing active TB within two months of the last infection (Stead, 2000:no page number). South Africa, in particular, “is burdened by one of the worst tuberculosis epidemics in the world, with disease rates of more than double those observed in other developing countries and up to 60 times higher than those currently seen in the USA or Western Europe” (Fourie, 2003:no page number). South Africa is also known to have extremely high rates of HIV infection and thus it can be expected that TB in many patients is recurrent. “The residual damage to the lung tissue after completion of tuberculosis treatment includes varying degrees of fibrosis, bronchiovascular distortion, emphysema and bronchiecstasis” (Hnizdo, Singh & Churchyard, 2000:36). A recent study on South African miners showed that the increasing number of episodes of TB corresponded

with an increasing loss of lung function (Hnizdo *et al.*, 2000:36). Hnizdo *et al.*, (2000:37) estimated that a:

“decrease in FEV₁ in subjects with one episode of tuberculosis was 326 ml after six months, 247 ml after one year, and stabilised at an average residual loss of 153 ml over the total follow up period; for subjects with two episodes of tuberculosis the temporal loss of FEV₁ was 499 ml after six months, 419 ml after 12 months, and stabilised at an average residual loss of 326 ml from 12 months onwards; while for subjects with three episodes of tuberculosis the temporal loss of FEV₁ was 583 ml after six months, 503 ml after 12 months, and stabilised at an average residual loss of 410 ml.” (Hnizdo *et al.*, 2000:37)

Hnizdo *et al.*, (2000:37) concluded that TB can cause chronic lung function impairment (with an increased obstructive pattern in the airways with increasing duration of the follow up period) which increases incrementally with the number of episodes of TB, affecting approximately 18% of subjects with one episode, 27% of subjects with two episodes, and 35% of subjects with three episodes of TB. Therefore, the large population of South Africans who suffer from TB, especially recurrent TB, are at high risk of developing COPD.

Gender, Race and Socio-economic Status

After standardization for smoking, males are more at risk than females for the development of COPD (ATS, 1995:S79; Fishman, 1998:662). Mortality rates are higher amongst whites than other races, although the difference is decreasing in males (ATS, 1995:S79). There is evidence that morbidity and mortality rates in COPD are inversely related to socio-economic status and are higher in blue-collar than white-collar workers (ATS, 1995:S79; Pauwels *et al.*, 2001:1260). Although according to Pauwels *et al.*, (2001:1260) it is not completely clear “whether this pattern reflects exposures to indoor and outdoor air pollutants, crowding, poor nutrition, or other factors that are related to socioeconomic status”.

Occupational Factors

Occupational factors are associated with increased prevalence of COPD, increased FEV₁ decline, and a higher mortality rate (ATS, 1995:S79). When the exposures to occupational dusts and chemicals (vapours, irritants or fumes) are prolonged or intense, the risk of COPD may be increased in the presence of concurrent cigarette smoking (Pauwels *et al.*, 2001:1260). “Many dusts cause mucus hypersecretion; persistent obstruction develops in coal and gold miners, farmers, grain handlers and cement and cotton workers” (Fishman, 1998:662). Cadmium workers have increased risk of emphysema (Barnes and Godfrey, 1997:3; Fishman, 1998:662). “Exposure to particulate matter, irritants, organic dusts, and sensitising agents can cause an increase in airway hyperresponsiveness, especially in airways already damaged by other occupational exposures, cigarette smoke, or asthma” (Pauwels *et al.*, 2001:1260).

CLINICAL FEATURES OF COPD

Patient History

COPD patients usually present in the fifth decade of life with a cough productive of sputum (Albert *et al.*, 1999:7.37.6), which manifests after an acute chest illness, and in the sixth or seventh decade of life COPD patients experience dyspnea on exertion (ATS, 1995:S81). “The typical patient who develops COPD has smoked more than 20 pack years before symptoms develop” (Albert *et al.*, 1999:7.37.6). Primary symptoms may include a history of “chronic, productive cough, episodic wheezing, and various degrees of shortness of breath increasingly associated with exertion, e.g., climbing stairs and carrying packages” (Mahler, 1990:12). Later in the course of the COPD an exacerbation may give rise to hypoxemia with cyanosis, the latter being exacerbated by erythrocytosis (ATS, 1995:S81). The sputum of a patient experiencing an exacerbation will generally increase in volume and become purulent (Albert *et al.*, 1999:7.37.6). “These episodes of acute bronchitis are usually accompanied by increased dyspnea, bronchospasm, and low-grade fever. As the disease progresses, the intervals between exacerbations shorten.” (Albert *et al.*, 1999:7.37.6)

Morning headaches suggest the presence of hypercapnia (Albert *et al.*, 1999:7.37.6). Weight loss occurs in some patients, and cor pulmonale with right ventricular failure and oedema may develop in those who have abnormal oxygenation (Albert *et al.*, 1999:7.37.6). “Bronchogenic carcinoma occurs with increased frequency in smokers with COPD” thus an episode of hemoptysis raises the possibility that a carcinoma has developed (ATS, 1995:S81).

Physical Examination

Visual examination of the patient may be unremarkable in the early stages of stable chronic obstructive pulmonary disease (George *et al.*, 1990:178). Calverley and Pride (1995:313) suggest that careful inspection rather than palpation or auscultation reveals the most useful physical signs of COPD. “It is important to observe the breathing pattern. Symptomatic patients will often have a prolonged expiratory phase and some will purse their lips in expiration. Patients adopting pursed lip breathing at rest usually have a severely reduced FEV₁ and hyperinflation” (Calverley and Pride, 1995:313). Forced contractions of the abdominal muscles can be seen throughout expiration, this increases at end exhalation (Albert *et al.*, 1999:7.37.7). Paradoxical indrawing of the lower chest wall, known as Hoover’s sign, is often evident (ATS, 1995:S81). “The patient at end-stage COPD may adopt postures that relieve and/or facilitate the function of accessory respiratory muscles (i.e. leaning forward while standing or sitting with the arms positioned on the knees or table), thereby reducing dyspnea” (Albert *et al.*, 1999:7.37.7). When the patient leans forward and supports him/herself the shoulder girdle becomes fixed and allows the muscles such as the pectorals and latissimus dorsi to be used for increased rib cage movement (Calverley and Pride, 1995:313). George *et al.*, (1990:178) name this the “tripod sign”. Mahler (1990:12) also reports on the appearance of a barrel-shaped chest amongst dyspneic patients.

Examination of the chest may reveal decreased breathing sounds, prolonged expiration and distant heart sounds (ATS, 1995:S81). “Coarse crackles may be heard at the lung bases. Wheezes are frequently heard, especially on forced expiration” (ATS, 1995:S81). As the

airflow obstruction progresses, however, hyperinflation of the chest becomes evident as the anteroposterior diameter of the chest increases (Albert *et al.*, 1999:7.37.7). The diaphragm flattens and becomes limited in its caudal motion (Albert *et al.*, 1999:7.37.7). Hyperinflation of the lungs is confirmed with a positive Hoover's sign.

COPD patients are divided into two extreme groups, the "pink puffers" and the "blue bloaters". "Pink puffers" are those who are dyspneic from vigorous breathing but maintain their arterial PO₂ and PCO₂ in an almost normal range (Murray *et al.*, 2000b:1634). The "pink puffer" usually presents with a slight body build, a tendency to lean forward over a support to assist breathing and the use of pursed-lip expiration (Barnes and Godfrey, 1997:11). The "pink puffer" has an overinflated chest, confirmed with radiographic images, with quiet breathing sounds and no adventitious sounds (West, 1995:57). The "pink puffer" usually represents with predominantly panacinar emphysema. The "blue bloaters" are those COPD patients who become cyanotic and oedematous because of hypoventilation with consequent hypoxia and hypercapnia (Murray *et al.*, 2000b:1634). The "blue bloater" is described as stocky and sometimes overweight (Baum and Wolinsky, 1994:987) with pronounced cyanosis at rest and mild exertion (Barnes and Godfrey, 1997:11). These patients also present with crackles at lung bases, a loud second heart sound in the pulmonary area as well as oedema of the ankles (Barnes and Godfrey, 1997:11). The "blue bloater" usually represents with predominantly centrilobular emphysema.

Signs of cor pulmonale may include jugular distension, an enlarged tender liver, patients may have right upper-quadrant tenderness and bilateral pedal oedema occurs (Albert *et al.*, 1999:7.37.7). "Kussmaul's sign (i.e. decreasing jugular venous pressures during inhalation) may be observed in the absence of heart failure, as a result of the compressive effect of lung inflation on cardiac filling" (Albert *et al.*, 1999:7.37.7). According to George *et al.*, (1990:179) the Doppler flow echocardiography is a sensitive technique for detecting cor pulmonale.

LABORATORY FINDINGS AND DIAGNOSTIC TESTS

Pulmonary Function Measurements

“Pulmonary function measurements serve to assess the severity of airflow limitation, to quantify the presence of the various abnormalities, and to identify and quantify reversible airflow limitation” (Murray *et al.*, 2000b:1190). Pulmonary function tests also help to determine the progress of the disease (ATS, 1997:S82).

Forced Expiratory Spirometry

“The forced expiratory spirogram is the most useful test of airflow dynamics” (Murray *et al.*, 2000b:1191). The spirogram is recorded as either a flow-volume or a volume-time plot (Barnes and Godfrey, 1997:14). It measures the maximal volume of air forcibly exhaled from the point of maximal inhalation (FVC) (Pauwels *et al.*, 2001b:1261); the volume of air expired in the first second (FEV₁); the middle half of the FVC (FEV₂₅₋₇₅); and the peak expiratory flow (PEF) (Murray *et al.*, 2000b:1261). The FEV₁, FVC, FEV₁/FVC ratio and the FEV₂₅₋₇₅ are all reduced as COPD progresses (West, 1982:71). The FEV₁ has little variation and is more accurately predictable from age, sex and height than the FEV₂₅₋₇₅ (Murray *et al.*, 2000b:1191). The reduced ratio of FEV₁/FVC is associated with obstructive diseases but is preserved in restrictive pulmonary disorders (Baum and Wolinsky, 1994:1002), making it an important measure to differentiate between the two disorders. FEV₁ is used in the diagnosis of COPD and in the determination of disease severity. “FEV₁ has been shown to correlate with death and disability in COPD and is considered an important staging criterion” (Berry *et al.*, 1999: 1248). *Table 2.1* illustrates the use of FEV₁ and FVC in COPD disease staging (Pauwels *et al.*, 2001: 1257). PEF is an estimate of the function of the larger airways and is very effort dependent (Barnes and Godfrey, 1997:14). “PEF is not as useful in COPD as in asthma, as it may be relatively well preserved in emphysema” (Barnes and Godfrey, 1997:14).

Table 2.1 GOLD Staging Criteria of COPD (Pauwels *et al.*, 2001:1257)

Stage	Characteristics
0: At Risk	Normal spirometry Chronic symptoms (cough, sputum production)
I: Mild COPD	FEV ₁ /FVC < 70% FEV ₁ ≥ 80% predicted With or without symptoms (cough, sputum production)
II: Moderate COPD	FEV ₁ /FVC < 70% 30% ≤ FEV ₁ < 80% predicted (IIA: 50% ≤ FEV ₁ < 80% predicted) (IIB: 30% ≤ FEV ₁ < 50% predicted) With or without symptoms (cough, sputum production, dyspnea)
III: Severe COPD	FEV ₁ /FVC < 70% FEV ₁ < 30% predicted, or the presence of respiratory failure, or clinical signs of right heart failure

The bronchodilator reversibility test is often performed at the time of diagnoses. A high dose (four puffs) of a beta agonist is given to the patient and spirometry is performed after 15 minutes (McAllister, 2002b:28). This test helps to eliminate the diagnoses of asthma, “to establish the patient’s best attainable lung function, to gauge a patient’s prognosis, and to guide treatment decisions” (Pauwels *et al.*, 2001:1261). “An increase in FEV₁ of 200ml and 15% demonstrates reversibility above that expected by chance, while an increase of 400ml or more suggest a significant asthma element” (McAllister, 2002b:28). Failure to reverse to normal or by more than 400ml, demonstrates irreversible airflow obstruction (McAllister, 2002b:28). Duek (2000:426) in the *Journal of Clinical Monitoring and Computing* recommends that the differentiation of asthma and COPD be based primarily on patient history of intermittent wheezing, reactivity to allergens and airway irritants as well as the bronchodilator reversibility test. Duek (2000:426) uses the reference value of at least 200 ml

or more than 12% increase in FEV₁ after the administration of a bronchodilator (clinicians generally apply a combination of the two reference values).

The expiratory flow-volume curve or loop is produced by most modern spirometers. The appearance of the flow-volume curve is highly characteristic in COPD (see *Figure 2.4*). The information from the flow-volume loop is also obtained as absolute values from the spirometer. An accurate diagnosis of COPD combines the spirometric readings with the patient's medical history.

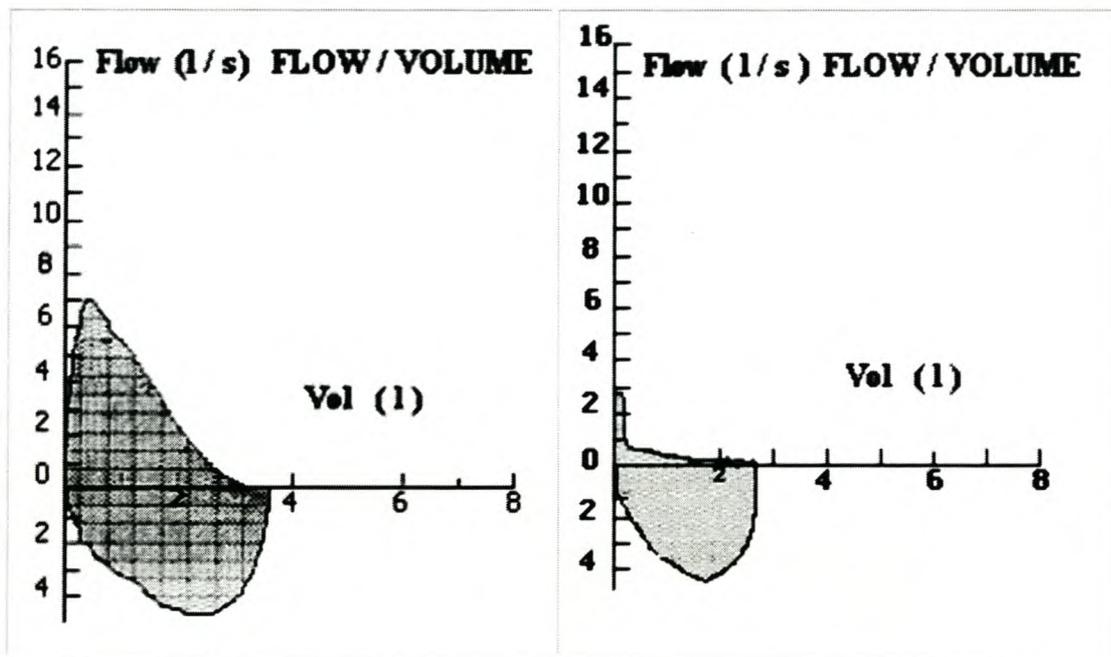


Figure 2.4. Flow volume loops showing normal (left) and severe airflow obstruction (right)

Lung Volumes

Spirometry alone is usually sufficient when evaluating the abnormalities of lung mechanics in COPD. However, lung volume measurement becomes necessary when the disease is very severe or there is doubt about the diagnosis, or when it is important to know the extent of the

emphysema (Barnes and Godfrey, 1997:16). Duek (2000:426) suggests the measurement of total lung capacity (TLC) when the COPD patient's FVC is less than 80% of the predicted value. This is to rule out superimposed restrictive pulmonary dysfunction and for assessing the severity of hyperinflation (Duek, 2000:426). Lung volumes are preferably measured with plethysmography but can also be measured by either the "washin or the washout of tracer gases such as helium" (Baum and Wolinsky, 1994:999). Patients with emphysema have typically increased TLC, functional residual capacity (FRC) and residual volume (RV) (West, 1995:60). TLC is increased due to the loss of elastic recoil that permits the inspiratory muscles to stretch the lungs to a greater maximal volume (Murray *et al.*, 2000b:1191). RV is increased because of airway closure at higher lung volumes, due to a combination of loss of elastic recoil and bronchiolitis (Murray *et al.*, 2000b:1191). FRC is increased because of loss of elastic recoil (Murray *et al.*, 2000b:1191). Expiratory reserve volume (ERV) and inspiratory capacity (IC) are slightly reduced in COPD (Barnes and Godfrey, 1997:18). Slow vital capacity (SVC) is reduced in more severe COPD and airways resistance (R_{aw}) is usually increased. Vital capacity (VC) is decreased due to the increase in RV (Murray *et al.*, 2000b:1191). Variations in the pattern of lung volumes is often seen in patients with mild to moderate COPD, these variations tend to disappear as the disease becomes more severe (Murray *et al.*, 2000b:1191).

Arterial Blood Gases

Measurement of arterial blood gases is important in advanced COPD patients (Pauwels *et al.*, 2001:1261). Pauwels *et al.*, (2001:1261) recommend that arterial blood gas measurements should be performed in patients with FEV₁ of less than 40% of predicted or with clinical signs that suggest respiratory failure or right heart failure. Arterial blood gases also "reveal mild or moderate hypoxemia without hypercapnia in the early stages of COPD" (Murray *et al.*, 2000b:1192). Arterial blood is usually sampled from the radial artery or from an indwelling radial artery catheter (West, 1995:17). Pauwels *et al.*, (2001:1261) find the finger or ear oximeters for assessing S_aO₂ less reliable than the measurement of blood gases via an actual blood sample. However, it is not always practical to take blood samples when needing an immediate blood gas reading and thus the pulse oximeter becomes necessary. Therefore, in

order to get the most accurate reading possible from a pulse oximeter, it is essential that users of pulse oximeters are familiar with the procedure and they are aware of the many factors that may affect measurements (Martin, 1999:96-97). Blood gas abnormalities worsen with exacerbations and potentially during sleep and exercise (Murray *et al.*, 2000b:1192).

Other

The volume-pressure relation is a measure used to measure the transpulmonary pressure at total lung capacity (Murray *et al.*, 2000b:1191). It is a measure that is seldom used in clinical practice but more as a research procedure. The single-breath diffusing capacity measures the distribution of ventilation in the lungs (Baum and Wolinsky, 1994:1000). Diffusion capacity (D_{LCO}) is decreased in COPD patients as the “emphysematous lungs have lost much of their alveolar surface and, thus, the area available for diffusion and the capillary blood volume are reduced” (West, 1995:65). This measure is not sensitive to low grades of emphysema.

Chest Radiography

According to the ATS (1997:S82) emphysema is most clearly evident on radiographic images of the lungs. Chronic bronchitis, however, cannot be diagnosed by chest radiographs, although radiographic signs may suggest the diagnosis (Murray *et al.*, 2000b:1190).

Two patterns (that are indicative of COPD) may show on radiographic images of the lungs. These are arterial deficiency and increased markings (Murray *et al.*, 2000b:1190). The pattern of arterial deficiency consists of overinflation, oligemia (deficiency in the volume of blood), and bullae (Murray *et al.*, 2000b:1190). This is characteristic of emphysema. Hyperinflation is indicated by a low and flattened diaphragm (Davies, 1981:34). (See *Figure 2.5* for the typical appearances of emphysema on a chest X-ray). The lateral image may show an increased retrosternal airspace and the heart shadow may look small as the heart is pulled down and rotated by the hyperinflation (Davies, 1981:35). The pattern of increased markings

is characteristic of chronic bronchitis (Murray *et al.*, 2000b:1190). Bullae are frequently seen on radiographic images of emphysematous lungs, they appear as curvilinear shadows enclosing empty airspaces (Davies, 1981: 36). Fishman (1998:633) does not advise radiographic images as reliable indicators of impairment or disability. Fishman (1998:633) states that there is a poor correlation between chest radiographic findings and pulmonary function abnormalities among patients with obstructive lung disease. Murray *et al.*, (2000b:1190) agree that emphysema patients show very little evidence on chest radiograph images until the disease is moderately advanced. According to the ATS (1997:S82), emphysema is consistently diagnosed when the disease is severe, but it is not diagnosed when the disease is mild and is diagnosed in about half the cases of moderate disease. Sub-cardiac air trapping also indicates hyperinflation. *Figure 2.5* shows a typical chest X-ray of an emphysematous lung (Mak, n.d.).



Figure 2.5. Typical chest X-ray of an emphysematous lung (Mak, n.d.)

Computed Tomography

Computed tomography (CT) has much greater sensitivity and specificity than standard chest radiography. High resolution CT can “diagnose emphysema accurately even before air flow obstruction has developed” (Baum and Wolinsky, 1994:303). High resolution CT can be used to help quantify the amount of air trapping by comparing images during inspiration and full expiration (Murray *et al.*, 2000b:1190). “When regional variations in lung tissue density are quantitated by CT scans, remarkably good correlations with the extent of anatomic emphysema can be demonstrated” (Baum and Wolinsky, 1994:997). CT is mainly used as an investigational tool. However, “precise knowledge concerning the anatomic distribution and severity of emphysema only rarely has practical implications in clinical management” (Baum and Wolinsky, 1994:997). The large expense of this imaging technique precludes its general application for the management of COPD.

Sputum Examination

In stable chronic bronchitis, sputum is mucoid, and microscopic examination reveals a predominance of macrophages (ATS, 1997:S82; Murray *et al.*, 2000b:1192). During an exacerbation the sputum is grossly purulent with an influx of neutrophils (Murray *et al.*, 2000b:1192). On the Gram’s stain there is an increase in the number of organisms seen (Murray *et al.*, 2000b:1192). “The most frequent pathogens cultured from the sputum are *Streptococcus pneumoniae* and *Haemophilus influenzae*. Other oropharyngeal flora, such as *Moraxella catarrhalis*, have been shown to cause exacerbations” (ATS, 1997:S82). Viral infections can also trigger an exacerbation of the disease. Outpatients seldom require a culture or Gram’s stain for institution of antimicrobial therapy (ATS, 1997:S82), unless the patient has sustained an exacerbation during or soon after receiving a course of antibiotic therapy (Murray *et al.*, 2000b:1192). Recent studies have shown that lower airway bacterial colonisation in stable state COPD plays a role in the character and frequency of COPD exacerbations (Patel *et al.*, 2002:759).

FACTORS THAT AFFECT EXERCISE TOLERANCE

Dyspnea

Dyspnea on exertion is the most frequent complaint of COPD patients (Mahler, 1990:168). Dyspnea is defined as “an uncomfortable awareness of breathing or an increased respiratory effort that is unpleasant and regarded as inappropriate by the patient” (Mahler *et al.*, 1984:751). Celli (2003b) explains dyspnea as a feeling of running out of air and being unable to breathe fast enough or deeply enough. “Other sensations include an awareness of increased muscular effort to expand the chest when breathing in or to expel air when breathing out, the uncomfortable sensation that inhaling (inspiration) is urgently needed before exhaling (expiration) is completed, and various sensations most often occur described as tightness of the chest.” (Celli, 2003b)

Dyspnea is usually first noticed when a COPD patient experiences an unusual amount of breathlessness climbing stairs or walking uphill. According to Mahler (1990:169) some patients with COPD experience disabling breathlessness when performing seemingly trivial upper extremity activities, such as combing their hair, bathing etc. The hyperventilation experienced by most COPD patients during exercise causes hypocapnia and subsequent symptoms of dizziness, palpitations, paresthesiae, faintness and sometimes chest pain (Folgering & Van Herwaarden, 1994:110). Dyspnea is progressive in COPD and as a result of the disturbing symptoms COPD patients tend to unknowingly reduce their level of activities. The reduction of activity leads to further deconditioning and further exercise limitation (Mahler, 1990:169). Dyspnea, however, has shown to decrease after exercise training. The reduction of dyspnea after exercise in COPD patients has thought to be attributed to desensitisation of COPD patients to dyspnea with reduction in fear and anxiety as a result of repeated exercise (Carrieri-Kohlman, 1996:1533). This is similar to methods used to treat persons with phobias in which they are repeatedly exposed to a stimulus over time in a safe environment which gradually lessens fear and anxiety associated with the stimulus. However, it is questionable whether desensitisation is the true mechanism of improved dyspnea levels. Carrieri-Kohlman *et al.*, (1996:1534) suggested repeated exercise facilitates

the development of coping strategies, such as pursed-lip breathing, rather than desensitising the patient to dyspnea. Carrieri-Kohlman *et al.*, (1996), undertook a very important study of the decrease of dyspnea in COPD patients after exercise training with coaching that included instruction in coping strategies, breathing techniques, and goal setting. This group of COPD patients was compared with a group of patients who exercised without coaching in a monitored environment. Carrieri-Kohlman *et al.*, (1996:1534) concluded that coaching does not significantly reduce dyspnea in COPD patients, “exercise alone is a powerful intervention for increasing exercise performance and decreasing dyspnea” in a monitored laboratory, as well as with ADL. The results of Carrieri-Kohlman *et al.*, (1996:1534) emphasize the “importance of having exercise training programs available to patients with chronic lung disease”.

Malnutrition

Twenty (20) – 70% of the COPD population are underweight compared with the ideal body weight (Engelen *et al.*, 1994:1793). Weight loss and low body weight correlate with increased morbidity and poor prognosis of patients with COPD (Engelen *et al.*, 1994:1793). “Malnutrition is common in patients with severe COPD. Patients’ lung function is often so poor that they cannot cook for themselves, and even eating a meal prepared for them can be a huge effort” (Fehrenbach, 2002:50). COPD patients experience elevated energy metabolism, which is not adequately met by a decreased spontaneous dietary intake (Schols, 1998:1791). Significantly reduced body weight in advanced chronic pulmonary disease is related to decreased exercise capacity (Shoup *et al.*, 1997:1576). A positive relationship between nutritional depletion and decreased peripheral and respiratory muscle strength is reported by Engelen *et al.*, (1994:1796), especially of the peripheral muscle groups. Shoup *et al.*, (1997:698) found a positive correlation between body weight and distance walked in the 12-minute walk test by COPD patients.

Nutritional depletion can be measured in different ways. Engelen *et al.*, (1994:1796) measured body weight as a percentage of ideal body weight adjusted for frame size and

height. Measures of body composition have also been used to assess the percentage of lean body mass. Such measures include the bioelectrical impedance method and the measurement of skinfolds. Body mass index (BMI) is a commonly used measure of nutritional depletion. The table below shows the classification of BMI in healthy individuals (ACSM, 2000:62). Specifically designed questionnaires have also been used to measure nutritional depletion.

Table 2.2. Classification of BMI (ACSM, 2000: 64)

	BMI, kg/m²
Underweight	< 18.5
Normal	18.5 – 24.9
Overweight	25.0 – 29.9
Obesity, class I	30.0 – 34.9
Obesity, class II	35.0 - 39.9
Obesity, class III	≥ 40

For healthy individuals the lowest health-risk category is that of individuals whose BMI ranges from 20 to 25, and the highest-risk category is that of individuals whose BMI exceeds 40. The suggested desirable BMI range for women is 21.3 to 22.1; for men, it is 21.9 to 22.4 (McArdle, Katch & Katch, 1996: 541). BMI, in healthy populations, has a “curvilinear relationship to the all-cause mortality ratio: as the BMI becomes larger, so also does the risk of a variety of diseases, such as cardiovascular complications (including hypertension), diabetes, and renal disease” (McArdle *et al.*, 1996: 541). BMI is a significant predictor of mortality and morbidity in COPD patients (Gray-Donald *et al.*, 1996:965). Shoup *et al.*, (1997:1579) found that either abnormally low or high body weight was associated with poorer health-related quality of life as determined by SGRQ. It is advised that the underweight COPD patient consult a dietician as weight loss has been found to be reversible with appropriate therapy amongst COPD patients (Schols, 1998:1796). Fehrenbach (2002:50) suggests the combination of exercise with modest weight reduction in COPD patients whom are overweight. “Weight loss in overweight patients reduces the energy requirements of

exercise and improves the ability of COPD patients to cope with the condition” (Fehrenbach, 2002:50).

Effects of Hypoxemia and Hypoxia

Hypoxemia is a “reduction in PO_2 below the normal range, regardless of whether gas exchange is impaired in the lung, C_aO_2 is adequate, or tissue hypoxia exists” (Pierson, 2000:50). Normal ranges of PO_2 are between 9.04 kPa and 10.11 kPa. Hypoxia exists when there is a shortage of oxygen in the tissues of the body (Pierson, 2000:50). There are several potential mechanisms for the development of hypoxemia, although in COPD patients the predominant mechanism is ventilation-perfusion (V/Q) mismatching (Pierson, 2000:50). In emphysema patients, the total surface area of the alveolar-capillary membrane is reduced and therefore the pulmonary capillary volume is also reduced, this leads to insufficient oxygen exchange at the membrane either by insufficient diffusion, or by a decreased contact-time at increased levels of cardiac output (Folgering and Van Herwaarden, 1994:110). Hypoxia triggers hypoxic pulmonary vasoconstriction and increases pulmonary vascular resistance. “If the hypoxia is prolonged, the increased right ventricular afterload produced by the chronically elevated pulmonary artery pressure results in hypertrophy of the right ventricle” (Pierson, 2000:47). If this process continues, eventually it will cause right heart failure with peripheral oedema, hepatic congestion and other signs of increased blood volume and elevated central venous pressure (Pierson, 2000:47). Physiologic responses to hypoxia include increased ventilation, respiratory alkalosis, pulmonary vasoconstriction, pulmonary hypertension, decreased maximum oxygen consumption and decreased myocardial contractility (Pierson, 2000:44).

Hypoxemia has an effect on pulmonary vasculature separate from alveolar hypoxia (Pierson, 2000:47). “Reductions in pulmonary capillary surface area caused by emphysema also contribute to the increased pulmonary vascular resistance. In addition, when present, erythrocytosis may further augment the pulmonary hypertension” (Pierson, 2000:47).

Pulmonary hypertension has an adverse effect on survival: the more severe the hypertension, the worse the prognosis.

Neurologic dysfunction seems to be a prominent manifestation of hypoxia, since the brain is one of the most oxygen-sensitive organs of the body. “Neuropsychiatric manifestations of chronic hypoxia can be a major source of morbidity in patients with COPD” (Pierson, 2000:45). According to Okubadejo, Jones & Wedzicha (1995:44), COPD patients are known to have impaired cognitive function and to suffer from depression.

Patients with severe COPD complicated by chronic hypoxemia complain of disabling breathlessness and reduced exercise capacity (Okubadejo *et al.*, 1995:44). Belman (1993:940) found that the “major differences between mildly and severely breathless patients were the presence of hypoxemia during exercise and an abnormally low diffusing capacity in the latter group.” Arterial hypoxemia may directly impair exercise performance by reducing oxygen delivery to working muscles (Gallagher, 1994:314). In normal subjects the imbalance caused by exercise in oxygen supply and demand to meet total body energy requirements leads to fatigue and eventually to task failure (Aliverti and Macklem, 2001:230). “Because hypoxia is a ventilatory stimulant, it can also limit exercise indirectly by causing ventilatory limitation at lower work rate than would occur in the absence of hypoxemia” (Gallagher, 1994:314). However, hypoxia as stated by Aliverti and Macklem (2001:233-234) is an unimportant limitation in exercise performance in COPD patients because breathing oxygen does not restore function to normal. This is possibly due to the reduced gas exchange in COPD at the alveolar-capillary membrane level. *Table 2.3* shows the signs and symptoms of hypoxia (Pierson, 2000:46).

Table 2.3 Symptoms and Signs of Hypoxia (Pierson, 2000:46)

Symptoms	Signs
(Dyspnea)	(Respiratory distress)
Restlessness	(Cyanosis)
Palpitations	Tachypnea
Confusion	Tachycardia
Agitation	Cardiac dysrhythmias
Headache	Hypertension
Tremor	Hypotension
Asterixis	Lethargy
Diaphoresis	Coma
Symptoms and signs in parenthesis are highly variable among individuals	

Steroid Myopathy

Ten (10) – 20% of COPD patients will show an improved FEV₁ with use of steroids (McAllister, 2002b:28). However, the risks of side effects are high. Among the side effects are myopathy and atrophy of the striated muscles of the limbs (Dekhuijzen & Decramer, 1992:997). Steroid-induced myopathy is also known to reduce muscle strength of the respiratory muscle groups (Decramer, De Bock & Dom, 1996:1958). Decramer *et al.*, (1997:421) expressed little doubt that the relationship between steroid treatment and muscle weakness is causal. Decramer *et al.*, (1996:1961) found that type IIa and IIb muscle fibres and type I fibres, to a lesser extent, were affected. Steroid-induced myopathy is first noticed by muscle weakness of the respiratory and peripheral muscles, largely elevated levels of creatine in the urine, and moderately elevated lactic dehydrogenase levels (Decramer *et al.*, 1996:1961). Respiratory muscle weakness is noted by enhanced dyspnea. Peripheral muscle weakness is usually first noticed with elevation of the arms or climbing of stairs. COPD

patients are more susceptible to muscle weakness as a result of a combination of factors including cardiac decompensation, malnutrition, electrolyte disturbances and blood gas abnormalities (Decramer *et al.*, 1996:1958). Dekhuijzen and Decramer (1992:1001) suggest that the treatment of steroid myopathy consists of reduced steroid dose and physical exercise to prevent or reverse steroid-induced muscle weakness.

Hyperinflation

Hyperinflation implies an abnormal increase in the volume of gas in the lungs at the end of tidal expiration - functional residual capacity (FRC) (Gibson, 1996:2640). Thus an increased residual volume (RV) and increased ratio of RV to total lung capacity (TLC), also known as air-trapping in the lungs (Gibson, 1996:2640). “The relaxation volume of the respiratory system (V_r) [or FRC] increases in patients with chronic airway disease as a result of changes in the elastic properties of the lungs and chest wall” (Gibson, 1996:2640). Hyperinflation results from the onset of inspiration before lung volume has fallen to V_r (Gibson, 1996:2640). “Hyperinflation of the thorax during breathing favors the preservation of maximum expiratory airflow, because as lung volume increases, elastic recoil pressure increases and airways enlarge; airway resistance decreases” (Fishman, 1998: 664). Hyperinflation thereby helps to compensate for increased airway obstruction. However, when the thoracic gas volume is increased the work of breathing is increased. (Fishman, 1998:664). “Hyperinflation places the patient on the upper flattened portion of the pressure-volume curve, increasing elastic work; and the development of auto-PEEP (positive end-expiratory pressure) creates a threshold that needs to be overcome with each breath” (Mador *et al.*, 2000:118).

A hyperinflated lung is represented radiographically by a depressed diaphragm and loss of its normal curvature (Gibson, 1996:2640). The flattened diaphragm is in a disadvantaged position for optimal function (Scharf, 1992:278). The diaphragm, as well as other inspiratory muscles, is placed in a shortened position (Scharf, 1992:278; Mador *et al.*, 2000:118). Contraction of the diaphragm further flattens the diaphragm and “the fibers pull the tendon progressively outward rather than downward, drastically reducing the diaphragm’s

mechanical advantage. Concomitantly, the flattened diaphragm pulls inward on its insertion, constricting the lower rib cage (Hoover's sign) (Scharf, 1992:278).

Dynamic hyperinflation occurs during exercise and readily develops in COPD patients with severe airflow obstruction and resting hyperinflation (Fujimoto *et al.*, 2002:457). "Resting and dynamic hyperinflation influence breathing patterns, inspiratory muscle function and neuroregulatory control during exercise" (O'Donnell *et al.*, 2002:663). According to Bauerle, Chrusch & Younes (1998:57) dynamic hyperinflation is also known to be the main consequence of expiratory flow limitation, especially at high levels of ventilation. A study by Foglio *et al.*, (2000:260) found that pulmonary hyperinflation was the strongest and most consistent correlate of impaired exercise performance. Murariu *et al.*, (1998:963) explain that in normal persons the tidal volume (V_T) during exercise is increased at the expense of both the inspiratory reserve volume (IRV) and the expiratory reserve volume (ERV), although even at maximum exercise capacity there remains a substantial IRV. In COPD patients, "any increase in V_T during exercise necessarily occurs at the expense of the IRV, and the end-inspiratory volume eventually approaches the total lung capacity" (Murariu *et al.*, 1998:963). COPD patients try to compensate for a reduction in their ventilation capacity by increasing their end-expiratory lung volume (EELV) during exercise to achieve higher maximal expiratory flows, yet this adaptive response places the respiratory muscles at a mechanical disadvantage (Carter *et al.*, 1993:745). Because of the increased lung volumes in dynamic hyperinflation, the inspiratory muscle pressure is increased for a number of reasons (Gallagher, 1994:312). The inspiratory muscles must generate sufficient pressure to overcome the combined recoil of the lungs and the chest wall at a higher lung volume for inspiration to take place (Gallagher, 1994:312). The inspiratory muscles also have to generate greater inspiratory pressures, compared to normal subjects, in order to overcome increased obstruction in the airways. During exercise the COPD patient has a greater V_E at a given work rate that further increases inspiratory demand (Gallagher, 1994:312). Dynamic lung compliance is significantly reduced in COPD patients, which results in a further increase in the elastic load (Gallagher, 1994:312). "The elastic load is increased owing to marked chest wall distortion during exercise" (Gallagher, 1994:312). Even though the load on inspiratory muscles is notably increased in

COPD the muscle strength is decreased (Gallagher, 1994:312). Therefore the stress on inspiratory muscles is remarkably increased in COPD patients during exercise.

During exercise the COPD patient experiences an increase in ventilatory demand, progressive air-trapping and further dynamic hyperinflation (O'Donnell, Reville & Webb, 2001:770). Bauerle *et al.*, (1998:65) found a significant correlation between dynamic hyperinflation and V_E amongst subjects with COPD. Thus the patient who experiences dynamic hyperinflation will experience concomitant dyspnea and with increased V_E , further dynamic hyperinflation (Bauerle *et al.*, 1998:65; Fujimoto *et al.*, 2002:457). The increased ventilatory requirements further exacerbate the imbalance between inspiratory muscle load and capacity and the predisposition to the early onset of respiratory muscle fatigue during exercise (Mador *et al.*, 2000:118). Thus COPD patients experiencing dynamic hyperinflation have reduced exercise capacity. Poor exercise performance is especially evident during arm work compared to legwork. According to Belman (1993:938) the stabilising effect of the shoulder girdle on the thorax is lost and inspiratory load is shifted onto the diaphragm and expiratory muscles. The diaphragm is required to assume a greater load, and as explained above, does not have the capacity to do so. This has important implications for COPD patients in activities of daily living (ADL) (Belman, 1993:938). “High inflation volumes may also affect cardiac performance and, thus, peripheral muscle function during exercise” (O'Donnell *et al.*, 2001:770).

Diaphragmatic Fatigue

“Respiratory muscle fatigue has been implicated in predisposing patients with advanced pulmonary disease to respiratory insufficiency” (Baum and Wolinsky, 1994:1229). “The diaphragm is the principal respiratory muscle, both because of its unique function in depressing the floor of the thoracic cavity and because of its effectiveness as an inspiratory muscle. The diaphragm is virtually always active during inspiration” (Scharf, 1992:278). The diaphragm consists of striated skeletal muscle and is predominantly made up of slow twitch muscle fibres and fast twitch oxidative glycolytic fibres (West, 1995:135). These fibres

are relatively resistant to fatigue but respiratory failure can occur if the work of breathing is increased over prolonged periods of time (West, 1995:135). Hyperinflation places the inspiratory muscles, particularly the diaphragm, in a shortened position and at a mechanical disadvantage. “During exercise, ventilatory requirements increase, further exacerbating the potential imbalance between inspiratory muscle load and capacity” (Mador *et al.*, 2000:118). Thus, COPD patients may be “particularly predisposed to the development of inspiratory muscle fatigue during exercise” (Mador *et al.*, 2000:118).

West (1995:135) reports on patients with severe COPD who continually breathe close to the work level at which fatigue occurs. “Fatigue is defined as the inability of a muscle to maintain a given force” (Bates, 1989:374). Increased ventilatory demand, during exercise or during an exacerbation of infection, will tip these patients over into a state of fatigue (West, 1995:135). A state of diaphragmatic fatigue will result in hypoventilation, CO₂ retention and severe hypoxemia. According to West (1995:135) a vicious cycle is initiated as hypercapnia impairs diaphragm contractility and severe hypoxemia accelerates the onset of fatigue. Malnutrition and steroid use also has a part in diaphragmatic muscle weakness. However, according to Dekhuijzen and Decramer (1992:997), the extent to which steroid use compromises diaphragm muscle fatigue is not fully understood.

Clinical manifestations of diaphragm fatigue include “tachypnea, paradoxical abdominal motion and respiratory alternans (variations between normal expansion and abdominal paradox), hypercapnia, and as a preterminal event, bradypnea” (Bates, 1989:374). It is possible to limit the dangers of diaphragm fatigue by reducing the work of breathing with treatment of the bronchospasm and controlling infection and by giving the patient oxygen to relieve hypoxemia (West, 1995:123).

Hypercapnia and Acidosis

Hypercapnia commonly accompanies severe airway obstruction, although it is generally not dangerous when blood pH is near normal (Celli, 2003b). Normal pH is between 7,35 and 7,45 (Zawada, 2003: no page number). Hypercapnia occurs due to two mechanisms, carbon dioxide (CO₂) retention from hypoventilation and ventilation-perfusion (V/Q) inequality (West, 1995:133). V/Q inequality is generally the culprit in severe COPD (West, 1995:134). Thus COPD patients must breathe more to maintain blood gases and pH, but cannot breathe as much as a normal subject due to obstructed airways as a direct result of COPD. Therefore CO₂ is retained and the body's pH level lowered. Respiratory acidosis is caused by CO₂ retention from alveolar hypoventilation, which results from a depressed central respiratory centre, restricted chest wall mobility and reduced pulmonary alveolar surface area (Zawada, 2003:no page number). COPD patients are at risk due to their poor ventilatory capacity to respond to hypercapnia or hypoxia (Zawada, 2003:no page number). "Respiratory acidosis is often accompanied by hypoxia" (Zawada, 2003:no page number).

Metabolic acidosis is a condition "characterized by a primary decrease in extracellular fluid bicarbonate; serum pH and carbon dioxide content are decreased" (Zawada, 2003:no page number). Metabolic acidosis occurs in COPD patients at rest and most often coexists with respiratory acidosis which complicates the pH abnormality further (West, 1995:135). A pH abnormality "is caused by the liberation of lactic acid from hypoxic tissues, and the dual factors of hypoxemia and an inadequate peripheral circulation are additive" (West, 1995:135). "Metabolic acidosis stimulates ventilation directly because of the fall in arterial pH. Metabolic acidosis may also increase V_E indirectly because of increased CO₂ production owing to buffering of acid" (Gallagher, 1994:315).

Metabolic acidosis develops in normal humans at high work rates but COPD patients tend to develop metabolic acidosis at lower work rates than normal healthy subjects (Gallagher, 1994:314). Lactic acidosis is a form of metabolic acidosis (West, 1995:32). Lactic acidosis occurs at the lactate threshold.

“The term lactate threshold refers to the highest exercise level (intensity) or level of oxygen that is not associated with an elevation in blood lactate concentration above the pre-exercise level (or an increase less than 1.0mM [mmol/dl]). The region in which blood lactate shows a systemic increase equal to or above a level of 4.0mM [mmol/dl] is termed the point of onset of blood lactate accumulation or simply OBLA.” (McArdle *et al.*, 1996:254)

Exercising muscles produce CO₂, which is added to the venous blood.

“The initial response is a linear increase in ventilation to remove this product of cellular respiration. The coupling is so efficient that arterial CO₂ and pH change little during mild and moderate exercise. During aerobic metabolism, muscle CO₂ production is directly related to oxygen consumption via substrate utilization. With higher-intensity exercise, lactic acid accumulation triggers additional CO₂ formation due to buffering of hydrogen ion (lactate) by bicarbonate. This leads to accelerated response in minute ventilation (V_E) in relation to oxygen uptake. The steep inflection in the linear relation between minute ventilation and oxygen uptake is termed the ventilatory threshold. Only with extreme exercise and high lactic acid production does metabolic acidemia ensue.” (Goldberg & Elliot, 1994:no page number)

Casaburi *et al.*, (1991:18) showed in their study of COPD that the lactate threshold was low in their patients and arterial lactate increased during unloaded pedalling. It is thought by Casaburi *et al.*, (1991:16) that the abnormal pulmonary vasculature in COPD patients contributes to their inability to supply adequate oxygen to the exercising muscles and thus an early onset of lactic acidosis during exercise. COPD patients also have a largely increased oxygen cost of breathing. McArdle *et al.*, (1996:257) state that the cost of breathing during exercise can easily reach 40% of the total exercise oxygen uptake. Thus there is further reduction in oxygen available for exercising muscles. COPD patients are most often untrained; this contributes to the premature development of lactic acidosis seen in these patients (Casaburi *et al.*, 1991:16). Untrained muscles are known to have higher levels of oxygen uptake compared to trained muscles at a given work intensity. Exercise training of COPD patients has shown to result in reduced V_E at a given work load and a fall in blood lactate (Casaburi *et al.*, 1991:16; Gallagher, 1994:315; Maltais *et al.*, 1997:560). Trained individuals are able to consume greater amounts of oxygen and the anaerobic proportion of exercise is smaller compared to untrained individuals (McArdle *et al.*, 1996:126). Lung hyperinflation also plays a role in hypercapnia. In a study by O'Donnell *et al.*, (2002:663), it

was shown that the severe mechanical constraints on ventilation as a consequence of lung hyperinflation in advanced COPD causes the tendency to develop CO₂ retention during exercise in patients with marked V/Q inequalities. Jonville, Delpech & Denjean, (2002) investigated the contribution of acidosis to exercise-induced diaphragmatic fatigue by measuring the twitch mouth pressure response to cervical magnetic stimulation of the phrenic nerves (this allows reliable and non-invasive measurement of respiratory strength during nonvolitional contractions). The subjects were required to perform two cycle tests, one while breathing spontaneously and the other test while voluntarily hypoventilating. Jonville *et al.*, (2002:1082) found the test performed while voluntarily hypoventilating resulted in significantly increased mean carbon dioxide in arterial blood and significantly decreased arterial pH when compared to spontaneous breathing. After the 10-minute spontaneous breathing test, the twitch mouth response was unchanged compared to the baseline values whereas the twitch mouth response fell significantly compared to baseline after the voluntarily hypoventilating test. The results of the study suggest that “exposure to hypercapnia may impair respiratory muscle function. This impairment could be more clinically relevant in patients with chronic obstructive lung disease” (Jonville *et al.*, 2002:1084).

“If muscle metabolism reaches its limits owing to a lack of oxygen, muscle metabolism is forced to anaerobic energy delivery, resulting in intramuscular acidosis thus terminating exercise” (Gosselink, Troosters & Decramer, 1996:978).

“Accompanying this blood lactate accumulation is a dramatic increase in H⁺ concentration in the active muscle, which can dramatically affect the intracellular environment. These alterations in contractile function are related to a depletion of intramuscular high-energy phosphates, an impaired glycolytic energy transfer capacity owing to the reduced activity of key enzymes, a disturbance in the tubule system for transmitting the impulse throughout the cell, and ionic imbalances. Certainly a change in Ca⁺ [calcium ions] distribution could alter the activity of the myofilaments and impair muscular performance. This would cause fatigue even though nerve impulses continue to bombard the muscle fiber.” (McArdle *et al.*, 1996:351)

Muscle fatigue occurs at reduced exercise intensities due to the early onset of lactic acid as a result of an accumulation of factors, primarily being the V/Q inequality that tends to occur in COPD patients. Thus, the lowered lactate threshold contributes to the low levels of exercise tolerance often experienced by COPD patients.

Symptoms of progressive respiratory failure are: metabolic encephalopathy with headache, drowsiness, and ultimately stupor and coma (Zawada, 2003). “Asterixis and myoclonus may develop” (Zawada, 2003).

Deconditioning

Due to shortness of breath during exercise, COPD patients tend to develop a sedentary lifestyle (Agusti *et al.*, 2003:351). As a result of reduced activity “COPD patients are subject to varying degrees of deconditioning” (Franssen, 2003:no page number). Physical inactivity causes a loss of muscle mass, reduced force generating capacity of muscle and decreased resistance to fatigue (Agusti *et al.*, 2003:351). Deconditioning is a common problem in COPD patients and often aggravates exercise tolerance (Belman, 1993:940). This initiates the “vicious cycle” of deconditioning (Clark, Cochrane & Mackay, 1996:2594). This “vicious cycle” occurs in COPD patients who have significantly reduced levels of physical activity and often avoid exertion due to dyspnea (Steiner and Morgan, 2001:73), due to this reduction in activity their exercise capacity is further decreased and patients then reduce their levels of activity even further. Celli (1999:196) states that the effect of training is lost after the exercise is stopped. Celli (1999:196) also mentions that it has been shown that bed rest resulted in a significant decrease in maximal oxygen consumption within 21 days. Atrophy occurs in COPD patients of both muscle fibre types as a result of deconditioning (Franssen, 2003:no page number). There is also a decline in oxidative enzyme activities in COPD, which is thought to be as a result of deconditioning (Franssen, 2003:no page number). Both contractile protein synthesis and activity of enzymes controlling energy metabolism are dependent on activity.

Cardiac Impairment

There is a large amount of evidence of abnormal cardiovascular responses to exercise in COPD patients. In COPD the pulmonary vascular resistance and pulmonary artery pressures are increased (Aliverti and Macklem, 2001:234) at rest. Elevated vascular resistance occurs mainly as a result of remodelling of the muscular arteries and arterioles, although emphysematous destruction of the vascular bed, alveolar hypoxia, increased haematocrit and acidosis also play a role (Belman, 1993:938). The right ventricular ejection fraction fails to increase during exercise in COPD even though:

“right ventricular end-diastolic volume is increased; and left ventricular end-diastolic, end systolic and stroke volumes are decreased, presumably secondary to the failure of the right ventricular ejection fraction to increase, or competition for space between the two sides of the heart within the pericardium.” (Aliverti and Macklem, 2001:234)

The right ventricular dysfunction is measured either by stroke volume-to-end diastolic pressure or right ventricular ejection fraction (Nici, 2000:698). According to Nici (2000:698) the causes for right ventricular dysfunction include:

“pulmonary hypertension, hypoxia, acidosis, and passive elevation of pulmonary artery pressure from left ventricular (LV) causes. In addition, the effects of intrathoracic pressure changes and extensive decreases in pleural pressure during inspiration can cause elevation of RV [right ventricular] afterload and RV [right ventricular] distention.” (Nici, 2000:698)

Barbera *et al.*, (2003:897) suggest that since pulmonary hypertension may develop at moderate levels of exercise, “repeated episodes of pulmonary hypertension during daily activities for example climbing stairs or even walking, could contribute to the development of right-ventricular hypertrophy”.

Cardiac output (Q_T) appears to increase normally during exercise in patients with COPD however at peak exercise, Q_T is about 50% of what a normal subject could achieve by

reaching a higher VO_2 (Agusti, 2003:354). According to Gallagher (1994:314), although Q_T response to exercise is normal, stroke volume (SV) is less and heart rate is greater in COPD subjects compared to normal subjects at the same VO_2 . Aliverti and Macklem (2001:234) report on findings of decreased Q_T during exercise to 39% of predicted, although they also do comment on the variability between patients suggesting that the severity of expiratory flow limitation is an important determinant of exercise Q_T . The O_2 uptake per heartbeat or O_2 pulse is characteristically low in COPD patients and may be a major factor limiting exercise performance (Nici, 2000:698). The low O_2 pulse is likely to be due to the low SV, which is as a result of the loss of pulmonary capillary bed (Nici, 2000:698). Aliverti and Macklem (2001:234) discussed the study of Morrison *et al.*, (1987) who found strong correlations between exercise O_2 consumption in COPD and right ventricular ejection fraction, exercise stroke volume and exercise cardiac output. Inadequate O_2 delivery is an important determinant of the impairment in exercise performance in COPD (Aliverti and Macklem, 2000:234). Aliverti and Macklem (2000:234-235) found that blood flow to the legs was not impaired in COPD subjects with peripheral muscle dysfunction, however they believe that the early lactate production that limited exercise could be related to the diminished capacity of exercising muscles to extract O_2 . Aliverti and Macklem (2000:235) concluded in their review of published literature that “poor exercise performance is due to failure to deliver oxygen to the exercising muscles. As this is not corrected by breathing oxygen, this failure must be due to relative ischemia” in the muscles, as mentioned above.

PULMONARY REHABILITATION

Introduction

The British Thoracic Society (1997:S13) defines rehabilitation as “the restoration of the individual to the fullest medical, mental, emotional, social and vocational potential of which he/she is capable”. AACVPR Pulmonary Guidelines Panel (1997:1364) defines pulmonary rehabilitation as:

“An art of medical practice wherein an individually tailored, multidisciplinary programme is formulated which through accurate diagnoses, therapy, emotional support, and education, stabilizes or reverses both the physio- and psychopathology of pulmonary diseases and attempts to return the patient to the highest possible functional capacity allowed by his pulmonary handicap and overall life situation.”

The common goal of pulmonary rehabilitation is to restore the patient to the highest possible level of independent function (Toshima, Kaplan & Ries, 1990:238; Cox *et al.*, 1993: 236; ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997:1363; Ketelaars *et al.*, 1997:363). This primary goal includes relieving symptoms, particularly dyspnea; improving functional ability and enhancing HRQL (Mahler, 1998:263S). Studies have shown that these goals are achievable. Foglio *et al.*, (1999a:128) found in their study of pulmonary rehabilitation that COPD patients in an outpatient setting had short-term improvements in exercise tolerance, dyspnea and quality of life. Wijkstra *et al.*, (1995:827) found that long-term improvements in quality of life were sustained for up to 18 months after a three-month rehabilitation programme. A study by Bendstrup *et al.*, (1997:2805) confirmed that an economical, comprehensive, and well-tolerated rehabilitation programme “can improve activities of daily living, quality of life, and functional capacity in patients with moderate-to-severe chronic obstructive pulmonary disease”. It is not entirely clear whether the improvements noted after pulmonary rehabilitation are “due to physiological changes such as improved neuromuscular coordination producing more efficient walking pattern or to predominantly psychological factors such as increased tolerance of dyspnea” (McGavin *et al.*, 1977: abstract). According to evidence-based guidelines by the ACVPR (1998:3), the following outcomes of pulmonary rehabilitation were demonstrated:

- Reduced hospitalizations and use of medical resources
- Improved quality of life
- Reduced respiratory symptoms (e.g. dyspnea)
- Improved psychosocial symptoms (e.g. reversal of anxiety and depression and improved self-efficacy)
- Increased exercise tolerance and performance

- Enhanced ability to perform activities of daily living
- Increased survival in some patients
- Return to work for some patients

It has been found in the review of literature that pulmonary rehabilitation is not entirely uniform but instead many researchers and authors have a unique set of components that make up pulmonary rehabilitation. The ATS (1999) suggests exercise training of the aerobic system, upper extremity endurance, lower extremity endurance and strength training as well as respiratory muscle training. The ATS (1999) also suggests the use of education and psychosocial and behavioural intervention in pulmonary rehabilitation. The ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel (1997) has similar components of pulmonary rehabilitation. There has also been mention of pulmonary rehabilitation, which includes smoking cessation therapy (Bendstrup *et al.*, 1997:2801), breathing retraining, evacuation of mucus, relaxation techniques and recreational activities (Cambach *et al.*, 1997:104). Calverley and Pride (1995:528) recommend the use of pharmacological therapy, education, physical therapy (breathing retraining, relaxation techniques, mobilization techniques, postural drainage, vibration and coughing), exercise conditioning, occupational therapy (ergonomics and vocational therapy), psychosocial support (counselling, psychopharmacological agents, group therapy, support of family, sexual counselling), oxygen therapy (if necessary), nutritional therapy and respiratory muscle training. Celli (1995) uses exercise training, respiratory muscles and breathing retraining, training of pursed lip and diaphragmatic breathing, education and psychological support. Of all the components of pulmonary rehabilitation, the ATS (1999:1671) states that exercise is the foundation of pulmonary rehabilitation.

Exercise in Pulmonary Rehabilitation

Exercises in pulmonary rehabilitation are known to include components such as interval training, endurance training, strength training of both upper and lower extremities,

desensitisation to dyspnea and training in ADL's. The most frequently mentioned components are endurance and strength training.

Strength Training

Hamilton *et al.*, (1995:2023) found, in a comparison of normal subjects with cardiorespiratory impaired subjects, that respiratory and peripheral muscle strengths, normalized for differences in age, gender and height, were significantly less in subjects with cardiorespiratory impairment compared to the normal group of subjects. Several factors contribute to peripheral muscle weakness. These weakening factors include hypoxemia, hypercapnia, steroid treatment, inactivity, and malnutrition. Inspiratory muscle function is also weakened due to the mentioned factors and is compromised even further as a result of hyperinflation of the lungs in some COPD patients (Gosselink *et al.*, 1996:978).

“The hypoxia that many COPD patients develop with exercise may limit exercise by reducing oxygen delivery to working muscles” (Gallagher, 1994:314). The abnormal cardiovascular function of most patients with moderate or severe COPD often limits exercise performance (Gallagher, 1994:317) because of the body's inadequacy to deliver sufficient oxygen to the muscles. According to a statement made by the ATS and the European Respiratory Society (1999:S6), studies of oxygen transport and oxygen utilization in COPD patients indicate that both oxygen delivery and oxygen uptake of the legs at peak exercise are limited most likely as a result of complex interactions involving central and peripheral (impaired oxidative capacity) factors. However, it appears that the blood flow and oxygen delivery to the legs during submaximal exercise is preserved and not any different from blood flow and oxygen delivery in untrained healthy subjects (A statement of the ATS and European Thoracic Society, 1999:S6).

“If muscle metabolism reaches its limits owing to lack of oxygen, muscle metabolism is forced to anaerobic energy delivery, resulting in intramuscular lactic acidosis” (Gosselink *et*

al., 1996:978). COPD patients were found to have significant lactic acidosis at low work rates (Casaburi *et al.*, 1991: 15-16). Maltais *et al.*, (1996:444) also found that compared to normal subjects, COPD patients show decreased skeletal muscle oxidative capacity and early exercise-induced lactic acidosis for a given work rate. Acidosis is thought by Gallagher (1994:317) to contribute to exercise limitation by impairing cellular function.

Nutritional status also has an effect on limb muscle strength and endurance (Belman, 1993:940). Malnutrition correlates significantly with low peripheral muscle strength. The reduced daily activities in COPD patients leads to a concomitant reduction in muscle function (Simpson *et al.*, 1992:70). Once the muscles are deconditioned, the COPD patient is likely to further reduce the daily activities performed and hence cause a downward spiral as the functional status of the COPD patient is reduced. However, it is evident from previous research that poor muscle strength amongst COPD patients is partially reversible and complements a purely aerobic exercise programme.

A study by Bernard *et al.*, (1999:159) compared two groups of COPD patients on a 12-week exercise programme. One group of patients performed an aerobic only training programme and the other group a programme of aerobic exercise combined with upper and lower body strength training. Bernard *et al.*, (1999:900) concluded that the addition of strength training to aerobic training in pulmonary rehabilitation is associated with significantly increased muscle strength and mass, but does not provide additional improvement in exercise capacity or quality of life. Clark *et al.*, (1996: 2590) compared a group of 32 COPD patients, who performed a 12-week training programme including peripheral muscle endurance and strength training, with a control group of 16 subjects. Clark *et al.*, (1996:2593) found significant improvements in the experimental group compared to the control group, in peripheral muscle endurance and strength and in a walking test. Clark *et al.*, (1996:2595) stated that the "benefits include not only increased endurance both of specific muscle activities and submaximal work, such as walking, but also reduced ventilation and breathlessness during exertion". As these are important functions of daily living they should be key aspects in the training of COPD patients (Clark *et al.*, 1996:2595)

The benefits of strength training are elaborated in the following two sections of literature.

1. Upper Extremity Strength Training

It was found by Lareau *et al.*, (1992:A476) that COPD subjects tended to perform arm activities that require the least respiratory muscle demand more frequently than those activities requiring sustained unsupported arm extension (washing hair, for example) or which require restricted diaphragmatic movement (bending forward to put on socks, for example). Lareau *et al.*, (1992: A476) concluded that arm activities that alter respiratory mechanics are limited in patients with severe COPD. According to Clark *et al.*, (1996:2596), in their study of weightlifting exercises in patients with COPD, activity of the upper limbs has a negative effect on diaphragmatic function. “During arm work the stabilising effect of the shoulder girdle on the thorax is lost and the inspiratory load is shifted onto the diaphragm and muscles of expiration” (Clark *et al.*, 1996:2594). The diaphragm is then required to assume a greater load even though the diaphragm is not sufficiently prepared to do so. The net result is that there is a greater limitation of arm than of leg exercise associated with the earlier onset of dyspnea (Clark *et al.*, 1996:2956).

A large number of studies have shown excellent results after upper extremity resistance training. The dyspnea experienced by COPD patients when performing activities using their upper extremities can be reduced by anchoring the arms so that the “muscles of the shoulder girdle (e.g. pectoralis major) can pull on the rib cage and contribute to ventilation. Upper extremity exercise training can augment the strength and endurance of these muscles, and thereby enhance inspiration” (Mahler, 1998:266s). Couser, Matinez & Celli, (1993) performed research on the effect of pulmonary rehabilitation that included upper extremity training. The research by Couser *et al.*, (1993:39) indicates that pulmonary rehabilitation which includes arm exercises significantly reduces the metabolic and ventilatory demands of a simple arm exercise in patients with COPD.

“Arm training also increases the capacity to perform arm work and decreases oxygen uptake [VO₂] for a similar amount of work. The exact reason for these changes is not clear. Possible mechanisms include desensitization to dyspnea, better coordination of the muscles partaking in arm elevation, and true metabolic adaptations.” (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997:1369)

Ries, Ellis & Hawkins, (1988:691) believe that a cross-over effect occurs between upper-extremity and ventilatory muscle function. In other words, an improvement in ventilatory muscle endurance occurs after upper body exercises (Ries *et al.*, 1988:691). However, a difference between unsupported arm training (against gravity) and arm-cranking was noted by Celli (1998:no page number). Celli (1998:no page number) found that unsupported arm training decreases oxygen uptake at the same workload compared with arm-cranking. Therefore, resistance training, preferably unsupported, of the upper extremities is an effective means of reducing the ventilatory and metabolic demands of daily activities that require the use of COPD patients' upper extremities.

Strength training of the upper extremities is encouraged for improved functional status in COPD patients. If the arms are trained to perform more work (or if the ventilatory requirement for the same work is decreased), the capacity to perform activities of daily living is likely to improve (Celli, 1998:no page number). The ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel (1997:1369) believes that “arm exercises are safe, and should be included in rehabilitation programmes for patients with COPD”. The ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel (1997:1371) concluded that: “the addition of arm training to leg training resulted in significant improvement in functional status when compared to either exercise alone.”

2. Lower Extremity Strength Training

According to the literature, COPD patients are often limited during exercise by leg muscle fatigue rather than by dyspnea (Haccoun *et al.*, 2002:1079). Killian *et al.*, (1992:939)

concluded from their study of weightlifting in patients with chronic airflow limitation that subjects were limited by the severity of leg muscle effort or fatigue more often than they were limited by dyspnea during an incremental exercise test. Killian *et al.*, (1992:939) suggested that COPD patients are likely not to be able to reach an adequate training response due to the severity of exercise-induced symptoms and it may lead to their dropping out of exercise programmes. In a statement made by the ATS and the European Respiratory Society (1999:S4), approximately 70% of chronic lung disease patients have lower quadriceps strength than the mean value obtained in normal subjects of similar age. Compared to subjects of similar age COPD patients have 20 to 30% less strength in their quadriceps muscles (A Statement of the ATS and European Respiratory Society, 1999:S4).

The benefits of lower extremity strength training are well documented. Bernard *et al.*, (1999:898) found significant reductions in V_E , heart rate and arterial lactate concentration for a given exercise work rate after strength and aerobic training of COPD patients. Bernard *et al.*, (1999:899) also noted a large improvement in the 6MWT. Bernard *et al.*, (1999:899) stated that improved peripheral muscle strength “may enhance exercise tolerance in patients with COPD. A greater strength of the quadriceps femoris muscle after training may reduce the perception of muscle fatigue, a common limiting symptom during exercise in patients with COPD”. Levels of dyspnea are reduced for a given work rate after strength training and are believed by Mahler (1998:265S) to be as a result of the corresponding fall in ventilatory demand during exercise (decreased V_E / work rate) as a result of enhanced mechanical efficiency. Lung function, however, does not improve after following of exercise programmes for the lower extremities (ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel, 1997:1365). Clark *et al.*, (1996:2594) found that low intensity exercises had benefits including increased endurance both of specific muscle activities and submaximal work, such as walking, as well as reduced ventilation and breathlessness during exertion. Walking is an important function of daily living and is generally a key target for training in patients with COPD (Calverley and Pride, 1996:2595). Another advantage of strength training is that it may encourage an increase of bone density in COPD patients - in whom osteoporosis is highly prevalent (Bernard *et al.*, 1999:900). Bernard *et al.*, (1999:900) also found that muscle resistive exercises induced little dyspnea and were well tolerated by COPD patients. The

resistive exercises also helped to diversify the training session and maintain patients' interest and motivation. The AACP/AACVPR Pulmonary Rehabilitation Guidelines Panel (1997:1369) concluded that: "there is substantial evidence that lower extremity exercise training should be included on rehabilitation programmes for patients with COPD. Benefits may be both physiologic and psychological".

Aerobic/ Endurance Exercise

"Endurance exercise training is the most important aspect of rehabilitation for patients with chronic pulmonary disease" (Cooper, 2001:S671). Aerobic exercise well above the anaerobic threshold is known to increase maximal exercise performance, cause physiologic adaptations in peripheral muscles and improve cardiac function (ATS, 1999:1671). Although exercise to date has not resulted in measurable effects on the underlying respiratory impairment, it has positive effects on dyspnea that underscores the importance of deconditioning as a co-morbid factor in advanced lung disease (ATS, 1999:1671). Maltais *et al.*, (1997:556) believe that improvements in exercise capacity as a result of endurance training can "usually be attributable to better motivation, desensitization to dyspnea, improved technique and performance, and, more recently, to enhanced respiratory muscle function".

Walking is necessary for most activities of living and thus is the preferred mode of training for many rehabilitation programmes (Celli, 2003a:no page number). "Because of training specificity, exercise programmes should provide training that parallels the desired outcome(s) as closely as possible" (ATS, 1999:1672). The "specificity principle" of training maintains that aerobic or cardiovascular exercise elicits specific endurance training adaptations, with only a limited interchange of benefits derived between strength and aerobic training (McArdle *et al.*, 1996:393-394). McArdle *et al.*, (1996: 393-394) advise that during specific activities, for example, walking, the overload must engage the appropriate muscles required by the activity and induce an exercise stress on the central cardiovascular system. Gosselink *et al.*, (1997:2886) agree that the principle of "training specificity" implies that the "work during exercise training should resemble conditions that are needed to be improved in COPD

patients, *i.e.* activities of daily living.” Maltais *et al.*, (1997:559) also encourage treadmill walking as a training modality because of its importance in daily living. Physical limitations may restrict the types of exercise training that can be used and although walking is the preferred exercise type, “some people may prefer exercising on a stationary bicycle” (Celli, 2003a:no page number). Cooper (2001:S671) suggests the mode of aerobic exercise should use large muscle groups of the legs (e.g., treadmill or cycle). A transfer effect has been shown when cycle ergometer training improved walking distance (Gosselink *et al.*, 1997: 2887). Celli (2003a:no page number) comments that it is important to choose an exercise that is comfortable and satisfying for the person in order to enhance long-term compliance.

Similar duration, intensity and frequency of exercise sessions are recommended throughout published literature. Clark (1994:276) recommends aerobic exercise of 20-30 minutes, three times a week. ACSM (2000:201-202) suggests intermittent exercise if necessary for the initial training sessions until patients can achieve sustained physical exertion. Cooper (2001: S671) and Mink (1997:no page number) are in favour of an accumulation of 30 minutes of exercise per exercise session at the target intensity, achieved by either continuous or interval training. 20 to 30 minutes of interval or continuous aerobic exercise is most often advised in order to elicit positive effects on COPD patients.

The research findings of optimal exercise intensity vary somewhat more than the generally agreed upon duration of 20 to 30 minutes' of aerobic exercise. The ATS (1999:1671) suggests a high intensity (60 to 80% maximal exercise capacity) alternating with equal periods of rest. In healthy subjects this form of training elicits training effects similar to those of endurance training, but it seems that its effect on COPD patients is unclear. Mink (1997:no page number) suggests that patients should aim to exercise at 60% to 80% of their maximum heart rate. It was realised by Mink (1997:no page number) that this goal may not be achievable for months, if at all. Mink (1997:no page number) recommends that the patient's capacity should be used as a guide. “If at first he or she can only exercise for 5 minutes - or even as little as 2 minutes - build on that. Patients should progress slowly; even small increments can make a significant difference in the quality of their lives” (Mink, 1997:no

page number). The ATS (1999:1672) claim that training patients at 60 to 75% of maximal work rate results in substantial increases in maximal exercise capacity and reductions in ventilation and lactate levels. Cooper (2001:S671) prefers the use of individual's maximum oxygen consumption (VO_2 max.) as a reference for intensity of exercise. Cooper (2001:S671) exercises COPD patients at a target intensity of 40% of VO_2 max. Gosselink *et al.*, (1997:2888) concluded in their review of exercise for COPD that low intensity exercise training (approximately 30% of maximal workload) resulted in modest improvements in submaximal exercise tests, but no improvement in maximal exercise performance was observed. In contrast, high-intensity training (approximately 60 to 80% of maximal workload) "improved both maximal and submaximal exercise tests and induced both cardiorespiratory and peripheral muscle adaptations" (Gosselink *et al.*, 1997:2888-2889). The review by Gosselink *et al.*, (1997:2889) demonstrated that high intensity exercise training is possible and safe in COPD patients. Maltais *et al.*, (1997:560) believe differently and associate high intensity training with increased cardiovascular risk and orthopedic injury and possibly decreasing compliance with the training programme. The ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel (1997:1369) are doubtful, stating that: "the optimal specific exercise prescription guidelines for the muscles of ambulation cannot be defined with certainty at this time". There is clearly uncertainty amongst the researchers regarding the optimal aerobic exercise intensity in pulmonary rehabilitation.

The use of a subjective scale of perceived exertion (RPE) is often used in pulmonary rehabilitation. "In the context of pulmonary rehabilitation, dyspnea during exercise testing or with physical activity during a programme is measured with either a Visual Analogue Scale (VAS) or Borg Scale that has been modified to measure breathlessness" (AACVPR, 1998:151). The modified Borg Scale has been found to have "strong and significant correlations with the VAS (Visual Analogue Scale) in patients with COPD ($r = 0.99$) with V_E ($r = 0.98$) and VO_2 [volume of oxygen] during exercise ($r = 0.95$). It has demonstrated sensitivity to treatment effects" (AACVPR, 1998:153). The advantages of the Borg Scale are that the adjectives help patients in selecting the sensation and intensity of the exercise and the "descriptors facilitate more absolute responses to stimuli and direct interindividual

comparisons, and the scale has been used in several randomised clinical trials allowing comparison of findings across studies” (AACVPR, 1998:153).

Gordon (1993:no page number) suggests that patients do not exceed a rate of perceived breathlessness (RPB) of five in the initial few weeks of the programme. Maltais *et al.*, (1997:561) used the Borg Scale successfully when adjusting the intensity of exercise in a pulmonary rehabilitation programme. Maltais *et al.*, (1997:557) increased the intensity of exercise if patients’ “Borg score < 5, unchanged in those with a score between a 5 and 6, and decreased when the score was ≥ 7 ”. The technique using RPE provides “a valid tool for monitoring for intensity of an exercise training programme” (Horowitz, Littenberg & Mahler, 1996:1173). See appendix for a model of the Borg Scale.

The frequency of exercise sessions is well documented. Literature suggests exercise frequency to be at least three times a week for optimal benefits of pulmonary rehabilitation (Mink, 1997; Ringbaek *et al.*, 2000:153; Cooper, 2001:S671). Ringbaek *et al.*, (2000:153) found in their study of COPD patients that exercise less than three times a week has no effect on exercise performance and well being of COPD patients. The duration of rehabilitation programmes differs amongst the literature but “based on publications after June 2000, the 2003 GOLD Update recommends a duration of ≥ 2 months for rehabilitation programmes” (Fabbri and Hurd, 2003: 2).

CHAPTER 3: STUDY DESIGN AND METHODOLOGY

ETHICAL APPROVAL

The study leaders were required to present a research proposal for approval to the Ethics Committee for Human Research of the Faculty of Health Sciences of Stellenbosch University. The study gained ratification by the ethics committee for its commencement, reference number 2002/C076.

SELECTION OF SUBJECTS

General practitioners and physicians of the Stellenbosch, Somerset-West and Paarl area were approached by a senior physician to nominate patients with COPD to take part in the study programme. The study was also advertised in the Somerset-West, Paarl and Stellenbosch local newspapers. An initial number of 17 subjects were tested for the study. Nine of the subjects qualified for the study according to the inclusion and exclusion criteria. A senior physician informed each of the subjects of the study protocol and what their role was in the study. Subjects were encouraged to continue with any other form of therapy that they were receiving at the time, for example physiotherapy treatment (these therapies were not recorded). Subjects were also encouraged to continue with their usual daily routines and to try to avoid any significant disruptions for the duration of the study. All subjects had to conform to the predetermined inclusion and exclusion criteria in order to be allowed into the study.

There was no control group. Each individual served as his/her own control. This is not an uncommon practice as can be seen in similar studies by well-known researchers published in very well established journals. Berry *et al.*, (1999), Foglio *et al.*, (1999), Couser, Martinez & Celli (1993) and Holden *et al.*, (1990) are some of the researchers who published work on research they did on pulmonary rehabilitation with COPD patients without the use of a control group. It was unethical to have a control group when most COPD patients were likely to

benefit from such intervention. It was unethical to help only one group of COPD patients and not others who are also in desperate need of help. According to a statistician the results of such a study without a control group can demonstrate significant results.

EXCLUSION CRITERIA

1. Serious illnesses or co-morbidities, for example cancer, chronic arthritis or claudication of the legs

Serious illnesses or co-morbidities were likely to interfere with exercise training. Pre- and post-intervention evaluations were likely to be obscured by other illnesses. For example, the measure of quality of life would be lower due to the other complications combined with the subjects' COPD status. Subjects were possibly also not able to complete the 6MWT due to reasons other than COPD, such as osteoarthritis. Post-intervention evaluations may have been affected by an exacerbation of cancer in the subject, for example. Changes in pre- and post-intervention evaluations would not be attributable to the status of COPD entirely had there been other complications.

2. Serious psychological disorders that would interfere with the rehabilitation process, for example, an inability to learn, severe depression or disruptive behaviour

The study was designed for subjects with COPD, other complications may have affected the ability of the subject to complete the exercise programme. Subjects with a psychological disorder may not have understood the study protocol completely and would perhaps not have been able to complete some of the tests correctly due to their difficulties in understanding. Emotional disturbances may also have limited motivation or have interfered with the ability to perform exercise training. For these reasons, the study outcomes would possibly have been adversely affected and false impressions would have been given of subjects' complete health

status. Study leaders were also not trained to deal with psychologically disturbed patients. The ATS (1999:1670) strongly recommended that psychologically unstable patients should be stabilized prior to entering a rehabilitation programme.

3. Known or suspected cases of ischemic disease, angina and right or left heart failure

The presence of ischemic disease, angina and right or left heart failure would have placed subjects at undue risk during exercise training. The study leaders were not prepared to take such risks. It was not possible for a physician to be present at every exercise session so the risk would have been even higher for subjects with cardiac complications.

4. One year or less post tuberculosis (TB)

TB is treated with a six-month course of medication. The changes in subjects with TB could possibly have been as a result of changes in the TB due to medication (or lack thereof) and not COPD disease status. Subjects needed to be uniformly COPD patients without confounding factors that might have altered the validity of the study results.

5. A grade four dyspnea on the Medical Research Council (MRC) dyspnea index (the criteria for the MRC dyspnea index are included in the appendix)

The physician, who medically screened all subjects before the onset of the evaluations and intervention programme, graded each subject according to the MRC dyspnea index. It was thought that subjects with a grade four dyspnea had COPD that was too severe for exercise without constant physician supervision. The MRC dyspnea index is a commonly used index and is relatively easily administered by appropriately trained pulmonologists or physicians.

6. Smokers of less than 10 pack years

Subjects had to have smoked for a minimum of 10 pack years. This was important for the homogeneity of the subject group.

INCLUSION CRITERIA

1. Subjects were diagnosed with COPD according to the GOLD criteria

The presence of post-bronchodilator $FEV_1 < 80\%$ of the predicted value in combination with an $FEV_1/FVC < 70\%$ confirms the presence of COPD according to the GOLD criteria (Pauwels *et al.*, 2001:1257). Subjects with a FEV_1 of $<65\%$ of the predicted normal value were allowed to participate in the study.

2. Subjects were mobile and could walk a distance of more than 80 metres in six minutes unaided

The 6MWT was an important measure of functional capacity in the study. Subjects that could not walk unaided were most likely to be hindered in the 6MWT by musculoskeletal problems and not necessarily by their COPD status. Subjects with musculoskeletal problems were unlikely to improve their disease status as they would not have been able to train at exercise intensities high enough to result in a significant training effect. This would also have affected the subject's ability to perform a number of the exercises in the intervention programme.

3. Subjects had to have their own transport and own telephonic communication

Subjects were required to be present at three exercise sessions every week, so subjects without transport could not be included in the study. It was important that subjects were contactable via telephone in cases of rescheduling of exercise sessions, reporting of illness and absenteeism. Most importantly, follow-up studies, using the same subjects, will rely on telephonic communication for subject motivation and in order to communicate any complications that have an effect on adherence to the exercise programme.

4. Subjects were willing to follow a 12-week rehabilitation programme

The programme was staged over a 12-week period. Individuals who missed six exercise sessions were considered for their continuation of the intervention programme. Thus it was important that the subjects were committed at the onset of the programme to being present at all 12 weeks of exercise. 12 weeks of exercise is likely to result in a significant training effect but periods of absenteeism would interfere with potential gains achieved in the exercise programme.

5. Age of 45 years and older

Subjects were homogenised by age. Only subjects of 45 years and older were allowed in to participate in the study.

6. Consent and support of the subjects' personal physician

In order to achieve maximum benefit from the exercise programme it was important that the study had the support of the subjects' personal physician. The study did not want to create

any illusions of taking the patients away from their physicians' practice, thus it was important that physicians were well informed of the study protocol and that their consent was gained. It was thought that subject adherence would be better if the study had subjects' personal physician's support. The study leaders informed the subjects' physicians of any complications that arose during the intervention programme. Subjects were also referred back to their physicians when necessary, for example, when illnesses or complications were detected during the intervention programme.

7. Completion and signature of an informed consent document before the commencement of the study (see appendix)

A senior specialist informed the subjects of the study protocol and what the study required of each subject. Subjects were issued with informing documents. If subjects agreed to participate in the study, they were asked to sign a form of consent before commencing with the initial evaluation procedure. See the appendix for a copy of the patient information and consent form.

8. Subjects who were in respiratory failure or desaturated to below S_aO_2 of 85% during the pulmonary evaluation were designated to train on inhaled oxygen

S_aO_2 levels were monitored continuously during the 6MWT. Subjects who desaturated to below 85% S_aO_2 were immediately given supplemental oxygen by way of an oxygen mask while continuing to complete the test. Subjects who required oxygen in the 6MWT were designated to use oxygen during the exercises in the intervention programme.

PRE-INTERVENTION PATIENT ASSESSMENT

Persons who were interested in joining the study contacted the clinical practice where all the testing took place. An appointment was made by interested persons to find out more about

the study and possibly to perform the pre-intervention tests. On subjects' arrival, a physician/pulmonologist explained the study protocol and what the subjects' role would be within the study. If subjects agreed to participate in the study they were requested to sign a document of informed consent and they were issued with complete information of the study protocol. Once this step was completed, a physician performed a medical screening and examination of each subject. The physician/pulmonologist completed the BDI, physician and patient global evaluations with the subject. If the subject still fell within the criteria of the study, the subject was tested further. Subjects who did not qualify for the study were told so and, if possible, they were asked to return to the study when they conformed to the study criteria. For example, if their blood pressure was uncontrolled they were referred to their personal physician and asked to return to the study when their blood pressure was controlled. The subject's mass and height was then measured and recorded by a clinical technologist. The pulmonary technologists took the subject's through lung function tests in order to derive the FEV₁ on a flow-volume curve. The lung function test was performed three times and the best value was recorded. Subjects whose lung function measured within the study's inclusion criteria continued to be given an ECG. FEV₁ was measured using a Jaeger Master Lab system, which was calibrated prior to the tests by a three litre jumbo syringe. The volume signal was integrated to calibrate flow. Subjects were then asked to complete the SGRQ with guidance of the study leader. Subjects who had completed all the tests successfully at this point were required to perform the 6MWT. The pulmonary technologist explained the procedure of the 6MWT to the subject. The subject was then given the opportunity to practice walking on the treadmill until they felt they had mastered it and were ready for the test. The subject was rested and then guided by the technologists throughout the test. Subjects' S_aO₂ levels and heart rate were recorded throughout the walk with the use of a pulse oximeter. The oximeter used was a BCI Oxi Pulse catalogue number 3301, serial number 320014739. Patients who desaturated to below 85% were given supplemental oxygen with a facemask. BP was recorded after each walk. Encouragement was given throughout the 6MWT. The 6MWT was performed three times with sufficient rest between tests. The following 6MWT was performed when subjects' heart rate and breathing rate had returned to resting values and the subject felt their legs were well rested. Distances were measured by the treadmill. The best distance was recorded. If subjects smoked they were recommended to stop and advised

to consult a clinic for stopping smoking. The subject was thanked and he/she made appointments to begin their exercise programme. The subject then began the intervention programme at the Biokinetics centre at the Department of Sport Science, Stellenbosch University.

INTERVENTION PROGRAMME

The intervention programme consisted of a 12-week exercise programme. Subjects were required to attend exercise sessions three times a week with no more than six days of absence in total. Exercises were targeted at improving the patients' deconditioned state as a result of COPD and its morbidities. The exercise programme had components of strength training exercises for the lower and upper limbs and a component of aerobic exercise. Subjects were required to perform all exercises at every exercise session.

Upper extremity exercises used resistance in the form of dumbbells or wrist weights. Resistance exercises of the upper extremities targeted the following muscle groups: *pectoralis minor* and *pectoralis major*, *upper trapezius*, *levator scapula*, *scalene*, *sternocleidomastoid*, *deltoids* and *biceps*. Subjects were encouraged to exhale with the extension of the upper extremities. The specific muscle groups chosen were in order to improve the ability of subjects to perform activities of daily living as well as to improve the strength of muscles used in the process of inspiration. One to three sets of ten repetitions were performed. The weight of the resistance was established using the Modified Borg Scale of Perceived Exertion. Subjects used weights equivalent to four (somewhat strong), five (strong) or six on the Modified Borg Scale. After each exercise subjects were asked to rate the activity on the Modified Borg Scale. The weight of resistance was adjusted accordingly. For example, if a subject rated an exercise as four or less on the Modified Borg Scale, the weight was increased slightly at the next exercise session or if the subject rated the exercise as seven or more, the weight of resistance was decreased. This method of monitoring exercise intensity was taken from a study Maltais *et al.*, (1997:557). Maltais *et al.*, (1997:558) concluded that this method was effective in improving exercise capacity; it was safe and was well tolerated by COPD

patients. High-intensity training is associated with increased cardiovascular risk and orthopaedic injury and possibly decreases compliance with a training programme (Maltais *et al.*, 1997:560). Maltais *et al.*, (1997:560) also concluded from their study that the training intensity used is not influenced by the age of the subject or the severity of the subjects' airflow obstruction. This method of determining exercise intensity is practically applicable and can easily be used by subjects in the future when exercising on their own.

Strength training of the lower limbs was included in the exercise programme. Strength training exercises for the legs was aimed at using gravity and subjects' own body weight as resistance. Exercises of the lower extremities made use of muscle groups that are used in ambulation and activities of daily living, namely the *quadriceps* muscle group; *hamstring* muscles; *gluteal* muscles and the hip flexor muscles. The intensity of the exercises was set according to the Modified Borg Scale of Perceived Exertion. Subjects performed lower extremity exercises at a RPE of four to six. Exercises to strengthen the abdominal muscles, *rectus abdominus* and *transverse abdominus*, in particular, were also part of the exercise programme.

Endurance exercises included walking and cycling. Walking was the most highly recommended activity, as it specifically uses the muscles of ambulation. A number of subjects in this study had very poor leg muscle strength or experienced joint problems in the lower extremities. These subjects were limited during treadmill walking due to premature leg muscle fatigue or joint pain before the subject reached the required intensity of training or a state of dyspnea. It was then decided to introduce cycling as an alternative form of aerobic exercise. Study leaders found that these subjects could train on a cycle ergometer at the optimal intensity according to their heart rate. Muscle groups used to cycle are similar to those used in ambulation, thus the principle of muscle specificity was applied and the improvement of leg muscle strength with cycling transferred to the act of walking.

Subjects exercised aerobically at a target heart rate of 60 –75% of maximum. This was taken from the ATS (1999:1672). The majority of successful rehabilitation programmes trained

subjects at 60 – 80% of maximum, as was discussed in chapter three. The use of a maximum of 75% of maximum heart rate ensured that subjects were not placed at cardiovascular risk while training. Target heart rate was calculated using the Karnoven method. The maximum heart rate used in the formula, was determined during the 6MWT. Subjects aimed to maintain the intensity for 20 – 30 minutes. If subjects were unable to exercise continuously they exercised intermittently until they could perform the exercise continuously. At first some subjects could only manage to walk for two minutes at one time so they walked two minutes then rested and then walked again when they had recovered from the first walk and then walked again if they felt they could. This was done until gradually their duration of walking was increased. Subjects were always encouraged to do their best.

SAFETY MEASURES

A number of safety measures were set in place in order to ensure that subjects were not at any unnecessary health risk and that emergency procedures were swiftly handled. Subjects were medically screened by a senior physician before entering the study. In this way any abnormal signs in the subject's health were identified. The inclusion and exclusion criteria were applied by the senior physician to exclude any subjects who may have been placed at an undue risk by exercise, for example, subjects with cardiac ischemia, angina or heart failure were excluded from the study. An ECG was performed on subjects before any form of exercise took place so cardiac abnormalities could be detected. S_aO_2 was measured during the exercise test via a finger pulse oximeter. Subjects who desaturated significantly to below 85% during the exercise test were either placed on supplemental oxygen or stopped from continuing the test until supplemental oxygen was given and the subject was able to continue with the test. Subjects who desaturated during the initial exercise test were designated to use supplemental oxygen throughout the intervention programme exercise sessions. A senior physician measured subjects' blood pressure before and after the 6MWT and heart rate was measured throughout the test by the pulse oximeter in order to detect abnormalities.

Safety during the 6MWT was vital. The exercise test was terminated under the following circumstances (ACSM, 2000:104)

1. Drop in systolic blood pressure of ≥ 10 mm Hg from baseline blood pressure despite an increase in workload
2. Hypertensive response (Systolic blood pressure of > 250 mm Hg and/or a diastolic blood pressure of > 115 mm Hg)
3. Subject requests to stop
4. Physical or verbal manifestations of severe fatigue
5. Onset of angina or angina-like symptoms
6. Signs of poor perfusion: pallor or cyanosis
7. Increasing nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
8. Failure of exercise testing equipment
9. Noticeable change in heart rhythm
10. Claudication or leg cramps
11. Increasing chest pain

Medical supervision was present at the subject evaluations to accommodate any emergencies that may have occurred.

On arrival at exercise sessions, subjects were seated and their blood pressure was measured and recorded by a study leader. A Polar heart rate monitor was used on subjects for continuous monitoring of their heart rate. Heart rate was recorded throughout the exercise sessions at specified times in order to maintain a record for future reference. Study leaders were hereby able to detect any abnormalities in heart rate rhythm, i.e. if subjects' heart rate increased too rapidly, if subjects' heart rate fluctuated drastically, if subjects' heart rate did not increase at all or even decreased with exercise. Therefore, if abnormalities occurred with subjects' heart rate rhythm it was possible to refer to the heart rate recordings when referring subjects to their physician for diagnoses. A physician/pulmonologist and Dr Viviers (from the student health department) were always available in case of an emergency. The

physician's and Dr Viviers's telephone numbers were kept close at hand. The physician and doctor were kept informed of the dates and times at which subjects were exercising. Any abnormalities in patients which occurred during the exercise sessions were discussed with the physician/pulmonologist. Subjects were referred to their personal physician for evaluation if necessary.

The following contraindications to exercise were used during the intervention programme (ACSM, 2000:167):

1. Unstable angina
2. Orthostatic blood pressure drop of >20mm Hg with symptoms
3. Acute systemic illness or fever
4. Severe hypertension at rest (i.e., systolic BP of > 200 mm Hg and/or a diastolic BP of > 110 mm Hg)
5. Uncontrolled tachycardia (>120 beats per min)
6. Uncontrolled atrial or ventricular arrhythmias causing symptoms
7. Uncontrolled symptomatic heart failure
8. Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
9. Recent acute exacerbation/ hospitalisation
10. Uncontrolled metabolic disease (diabetes, for example)
11. Significant emotional distress (psychosis)

MEASUREMENTS

Six-Minute Walk Test (6MWT)

Aim

The 6MWT was used to evaluate subjects' aerobic functional status at pre and post-intervention evaluations.

Description

The six-minute walk test required subjects to walk as far as possible in six minutes. Subjects walked on a treadmill. Clinical technologists, who specialised in pulmonology, tested subjects on the 6MWT. The test protocol was explained in detail and any questions subjects had, regarding the test, were answered. If subjects had not used a treadmill before, they were given time to become familiar with walking on the treadmill. Subjects were then given time to rest before the test began. Subjects were encouraged throughout the test to walk as fast as they could. If the subject said that they wanted to walk faster, or rather slower, the technologist would adjust the speed of the treadmill accordingly until the six minutes ended or the test was terminated. Subjects were given sufficient time to recover and the test was performed again. The test was performed three times and the longest distance walked was recorded. Subjects used oxygen supplementation if S_aO_2 , as measured by a pulse oximeter, dropped to a level of below 85%. The threshold of noticeable difference in functional status is 54 m (Redelmeier *et al.*, 1997:1280). Subjects' blood pressure was measured directly after the test in order to monitor subjects' cardiovascular response to the exercise. Subjects were also asked to rate their test on the modified Borg Scale. Subjects' RPE determined the amount of effort that subjects had placed on their 6MWT. Subjects who rated their RPE as

below five had obviously not put all their effort into the test and had to repeat the test at a RPE which was closer to their maximum effort.

Reliability and Validity

The six-minute walk test is a reliable, valid, safe and inexpensive measure (Redelmeier *et al.*, 1997:1278). The six-minute walk test can also be applied regardless of a patient's age, gender, or level of literacy (Redelmeier *et al.*, 1997:1278). The test is simple, easy to administer and uses an exercise mode relevant to everyday activities (Guyatt *et al.*, 1984:818).

“The 6MWT provides information that may be a better index of the patients ability to perform daily activities than is peak oxygen uptake; for example the 6MWT correlates better with formal measures of quality of life. Changes in 6MWT after therapeutic interventions correlate with subjective improvement in dyspnea. The reproducibility of the 6MWT appears to be better than the reproducibility of the 1-second forced expiratory volume in patients with chronic obstructive pulmonary disease.” (ATS, 2002a:112)

Stevens *et al.*, (1999:1543) found the 6MWT performed in a hallway and on a treadmill have similar intratest reproducibility when three walks are performed in a single test session. The intratest variability of the three hallway 6MWT's was similar to the three treadmill 6MWT's and no significant difference in the coefficient of variation was found (Stevens *et al.*, 1999:1543). A study by Knox, Morrison & Muers (1988) of the reproducibility of the 6MWT over several days indicates that the majority of the increase in walking distance occurs within the first three tests.

St George's Respiratory Questionnaire (SGRQ)

Aim

The SGRQ was used in our study to assess HRQL of subjects. Subjects were required to complete the SGRQ before and after the intervention took place. Changes in the pre-intervention score compared with the post-intervention score indicated a change in the subject's HRQL.

Description

The SGRQ is a disease-specific questionnaire that measures the quality of life of COPD patients. The questionnaire is self-administered. It contains 50 items and 76 weighted responses divided into three components: Symptoms, Activity, and Impacts. The Symptoms component includes questions concerning the frequency of the patient's cough, sputum production, wheezing, breathlessness, and the duration and frequency of breathlessness or wheezing. The Activity component includes items concerning physical activity that cause or are limited by breathlessness. The Impacts component concerns employment, the feeling of being in control of health, panic, stigmatisation, the need for medication and its side effects, expectations for health and disturbance of daily life. The score ranges from zero to 100. The total score is calculated for each component and a total score for the test is given. Zero indicates no impairment of quality of life while 100 indicates extreme impairment related to COPD. The questionnaire takes about 10 minutes to complete

Subjects completed the questionnaire in a quiet room where a study investigator was present to help subjects with any queries. The questionnaire was presented in Afrikaans and in English. The investigator was careful not to answer the question for the subjects but tried to help subjects arrive at their own conclusion. The total score was calculated following the procedures devised by the developers of the questionnaire. A mean change in score of four

units was associated with slightly efficacious treatment, eight units for moderately efficacious change and 12 units for very efficacious treatment (ATS, 2002b:no page number). The advantages of this instrument are that it is self-administered, has computerized scoring, and has had extensive psychometric testing.

Reliability and Validity

Jones *et al.*, (1992:1326) confirmed in their study that the SGRQ has a good repeatability, it correlates with a range of established measures of disease activity. The SGRQ is a very sensitive measure of improvement or deterioration in the health of patients with chronic airflow limitation. Wilson *et al.*, (1997:536) also state that to date the SGRQ has been shown to be reproducible, valid and responsive in COPD populations.” (Wilson *et al.*, 1997:536).

Baseline Dyspnea Index (BDI) and Transitional Dyspnea Index (TDI)

Aim

The Baseline Dyspnea Index and the Transitional Dyspnea Index are measures of breathlessness in COPD patients. The BDI was used as an initial evaluation of dyspnea while the TDI measured change in subjects' dyspnea status after the intervention programme.

Description

The dyspnea indices are multidimensional questionnaires (O'Donnell *et al.*, 1995:2006). The BDI measures dyspnea at the initial assessment while the TDI is designed to assess changes after some intervention over time and is related to the initial BDI assessment (Calverley and Pride, 1995:224). The questionnaires assess three different attributes – functional impairment

(the degree to which ADL's are impaired), magnitude of effort (the overall effort exerted to perform activities and the magnitude of task that provokes breathing difficulties. The focus is on the activity consequences of the individual's breathlessness. "An interviewer uses a patient history in each category. Ratings on these scales are summed to obtain a focal score" (Lareau *et al.*, 1994:243). The BDI is out of a total of 12 points: four points per attribute. Each attribute ranges from zero (very severe impairment) to four (no impairment). Therefore the higher the score achieved by the subject the less dyspnea is experienced. The TDI was evaluated after the intervention programme in order to measure change from the BDI score. Each category receives a score from plus three (major improvement) to minus three (major deterioration). The total change in dyspnea status (TDI) is then calculated by adding the score of all three categories, total scores range from minus nine to plus nine (Carrieri-Kohlman *et al.*, 1996:1528). [See appendix for examples of the questionnaires]. The senior physician scored subjects on these indices at the first and second evaluation at the beginning of each evaluation, before the spirometry, SGRQ or 6MWT took place.

Reliability and Validity

The BDI is known to be a valid and reliable measure of breathlessness amongst COPD patients. "Previous studies have demonstrated the validity and reliability of the BDI in patients with chronic respiratory disease" (Mahler *et al.*, 1992:396). The TDI has been shown to detect changes reliably in symptom intervention over time in each of the three categories (O'Donnell *et al.*, 1995:2006).

Forced Expiratory Volume in One Second (FEV₁)

Aim

Forced expiratory volume in one second was measured at both evaluations with the use of a Jaeger Master Lab. Subjects were seated for the test and a nose clip was used. The severity of obstructive airways disease is judged on the basis of the absolute value of the FEV₁ or as a percentage of the predicted FEV₁ (Schorn, 2001:5). Both measurements were recorded for statistical analysis. The measurement was also to test for reversibility of airway obstruction with the use of a post-bronchodilator measurement lung function. If the obstruction was partially or totally irreversible, then the possibility of a diagnosis of asthma could be ruled out. FEV₁ is the most commonly used measure of disease state.

Description

FEV₁ is the “volume of air exhaled in the specified time during the performance of FVC, e.g., FEV₁ for the volume of air exhaled during the first second of FVC” (ATS, 1987:1287). Lung volumes are expressed in litres. “In performing the forced expiratory vital capacity manoeuvre, the person first inspires maximally to the total lung capacity, then exhales into the spirometer with maximum expiratory effort as rapidly and as completely as possible” (Guyton and Hall, 1996:539). Subjects were adequately prepared for the test by experienced pulmonary technologists. The procedure was explained and demonstrated to subjects, who were then encouraged to make the maximum effort when undergoing the test. The measurements taken were compared with normal predicted values for age, sex, weight and height. “An individual with a normal lung will exhale about 80% of the forced vital capacity (FVC) in 1 s [FEV₁]...if the airways are obstructed, the rate of flow will be less than normal” (Prange, 1996:57). The test was performed three times and the best value was recorded. If a discrepancy of more than 10 % was found between the first three tests, further tests were done until the results could be repeated consistently. The bronchodilator reversibility test was used

to rule out the diagnosis of asthma. Three puffs of a bronchodilator were administered to subjects and 15 minutes was allowed for the optimal activation of the medication. The spirometric test was repeated. The possibility of asthma was considered if the FEV₁ increased to more than 80% of predicted normal values. All asthmatics were excluded from the study. The bronchodilator was only used in the pre-intervention not in the post-intervention evaluation. Subjects with a post-bronchodilator FEV₁ of less than 80% of predicted and a FVC/FEV₁ ratio of less than 70% of predicted were diagnosed with COPD and qualified for entry into the study. No changes in FEV₁ were expected as it is known that the magnitude of airways obstruction is not a good predictor of response to pulmonary rehabilitation (ZuWallack *et al.*, 1991:808).

Validity and Reliability

The diagnosis of airflow limitation is based on pulmonary function measurements, commonly FEV₁ (Petty and Weinmann, 1997:248). COPD patients with a low FEV₁ are more likely to show rapid decline in pulmonary function and are more likely to die from COPD (Croxton *et al.*, 2002:840). The FEV₁ is the most commonly used criterion for diagnosis and prognosis of COPD. FEV₁ does not, however, reflect any change caused by pulmonary rehabilitation.

Body Mass Index (BMI)

Aim

BMI was measured to assess body weight relative to height. Measurements of BMI were taken before and after the intervention programme to measure any change in relative body mass.

Description

BMI is calculated by dividing body weight in kilograms by height in metres squared (kg/m^2). Subjects' height was measured on stadiometer using the metric scale. Subjects' mass was recorded on an electronic scale in kilograms at pre and post-intervention evaluations. An example of BMI classification is displayed in the literature review.

Reliability and Validity

The BMI score is repeatable provided the same scale is used for measuring body mass at both evaluations. BMI scores are easy to obtain and can reliably be used for all individuals of any gender or age.

Physician Global Evaluation

Aim

The physician global evaluation is a physician's assessment of the overall condition of the patient's COPD status.

Description

The physician's global evaluation is scored from zero to eight with categories of poor, fair, good and excellent health. The physician bases the score in terms of: concomitant therapy; number and severity of exacerbations; severity of cough; ability to exercise and amount of

wheezing. The same investigator at pre- and post-intervention evaluations performed this assessment.

Validity and Reliability

The physician global evaluation is a measure of respiratory health universally used in COPD studies and by physicians and pulmonologists. The physician global evaluation is also used frequently in pulmonological research. An experienced clinician recommended the method of evaluation. No literature is currently available regarding the physician global evaluation, however, a number of published studies have used this evaluation in the past. For example, the randomised double-blind placebo controlled parallel group efficacy and safety comparison of a one-year treatment of two doses of Tiotropium inhalation solution delivered by a Respinap inhaler in patients with COPD. 870 patients were randomised, 270 have completed the trial. This international trial was performed by Boehringer Ingelheim, trial number 205.255.870, at a number of different centres around the world.

Patient Global Evaluation

Aim

The patient global evaluation was administered in order to give a further idea of how subjects perceived their own health.

Description

The patient global evaluation consists of a thermometer like scale where 100 is absolute health and zero is the worst level of health. The patient is asked to rate his/her present health on the scale, as they perceive it.

Validity and Reliability

The patient global evaluation is an easy and quick method of evaluating a subject's perception of his/her own health. The patient global evaluation is used extensively in drug trial research.

POST-INTERVENTION ASSESSMENT

The post-intervention evaluation again took place at the same venue as the first evaluation. A physician first conducted a medical examination on subjects. The physician/pulmonologist recorded the TDI, patient's and physician's global scores. Subjects' body mass was recorded by a pulmonary technologist. Subjects then performed the lung function tests. The best of three lung volumes was recorded. Subjects completed the SGRQ. Subjects were then tested on their performance in the 6MWT. Again three tests were performed and their best distance was recorded. The physician/pulmonologist gave subjects a summary of the changes in their health over the duration of the study.

DATA ANALYSIS

Each subject served as his/her own control. Results of the second evaluation were compared with the results of the first evaluation. The ANOVA test and the Wilcoxon method were used

to analyse the data of all the variables tested except the BDI and TDI which were analysed using the sample t-test.

ABSENTEEISMS AND COMPLICATIONS

The study proved difficult in terms of subjects' handicaps and complications that they incurred during the intervention programme. Some complications prevented subjects from attending exercise sessions or forced the study leaders to postpone the date of subjects' evaluations. Other complications did not stop subjects from attending exercise sessions but the complications may have hindered subjects' rate of progress in the intervention study. All subjects, however, continued with the exercise programme and remained motivated to persevere (apart from one subject) for the duration of the 12-week programme.

Three of the subjects experienced orthopaedic complications during the intervention programme. One of the subjects fell at home and suffered from a severe haematoma on her right knee two weeks before her second evaluation was to take place. She was restricted to bed rest for three to four weeks and her evaluation was postponed by two weeks. A second subject suffered a grade I sprain to her ankle while she was walking at her home, she was unable to attend exercise sessions for a week. Two subjects did not disclose the complications regarding their joint injuries at the first evaluation. One subject had been involved in an accident a few years previously in which she had incurred severe joint injuries; these injuries meant that she performed the exercises at a lower intensity and at a slower rate of progression. A third subject suffered from severe osteoarthritis of the shoulders, knees, hips and vertebral column. This subject was able to perform all the exercises but it was advised that he uses the stationery cycle as part of his cardiovascular exercise routine due to the impact of prolonged walking on his hips, knees and back.

Two of the subjects began to experience atrial fibrillations while exercising. Both subjects were medicated successfully by their physicians and were able to continue with the

intervention programme soon after. Another subject was hypertensive, which prevented her from starting the intervention programme for a week until her blood pressure was controlled with medication.

Some subjects suffered from acute exacerbations and chest infections. They were usually treated by their doctors and did not attend the exercise sessions until they had recovered. One subject suffered from a number of acute exacerbations that forced her to miss more than the maximum of six sessions. She did, however, remain motivated and continued with the exercise programme to make remarkable gains in her health, as was measured at the pre- and post-intervention evaluations.

Two subjects were unable to attend a number of sessions due to business and travel commitments. One of the subjects was very unmotivated and skipped exercise sessions for unexplained reasons. She missed a total of nine exercise sessions. The same subject smoked 40 cigarettes a day although she was encouraged to stop on numerous occasions during the intervention programme. Two other subjects continued to smoke during the intervention programme, albeit they smoked far less than 40 cigarettes every day. These two smokers claimed to only smoke about 10 cigarettes in a day. These subjects were not excluded from the study although their results were likely to have been influenced by their smoking habits and their absence from a number of exercise sessions.

The inclusion and exclusion of subjects is demonstrated clearly in *Figure 4.1* on page 85.

CHAPTER FOUR: DATA ANALYSIS

SUBJECTS

A total of nine subjects completed the study programme out of 17 subjects who were initially evaluated. Eight subjects withdrew/dropped out or were ineligible for the study. Two subjects suffered from claudication upon performing the exercise test. These subjects were unable to continue with the intervention programme until they had received further medical attention. These two subjects were referred to vascular specialists but did not return to the study for reasons unknown to the study leaders. A third subject was unable to walk without a walking frame. This person was excluded from the study according to the study's predetermined exclusion and inclusion criteria. Another subject presented with an Achilles tendon rupture and was unable to perform the exercise test or any further exercise intervention. A fifth subject who qualified for the study left shortly after the initial evaluation for an extended overseas holiday and did not return. The sixth subject decided for his own personal reasons that he did not want to participate in the study. The seventh subject qualified according to the criteria set for the study but lung function tests showed that her FEV₁ was normal (more than 80% of the predicted normal value) and was not low enough to qualify for the study. The final subject who did not complete the intervention programme did qualify for the study but she dropped out after two weeks due to the expense of travelling to the exercise venue three days in a week for 12 weeks. In total, nine subjects completed the intervention programme. Figure 4.1 provides an illustration of the subjects who dropped out, were ineligible and those who completed the intervention programme.

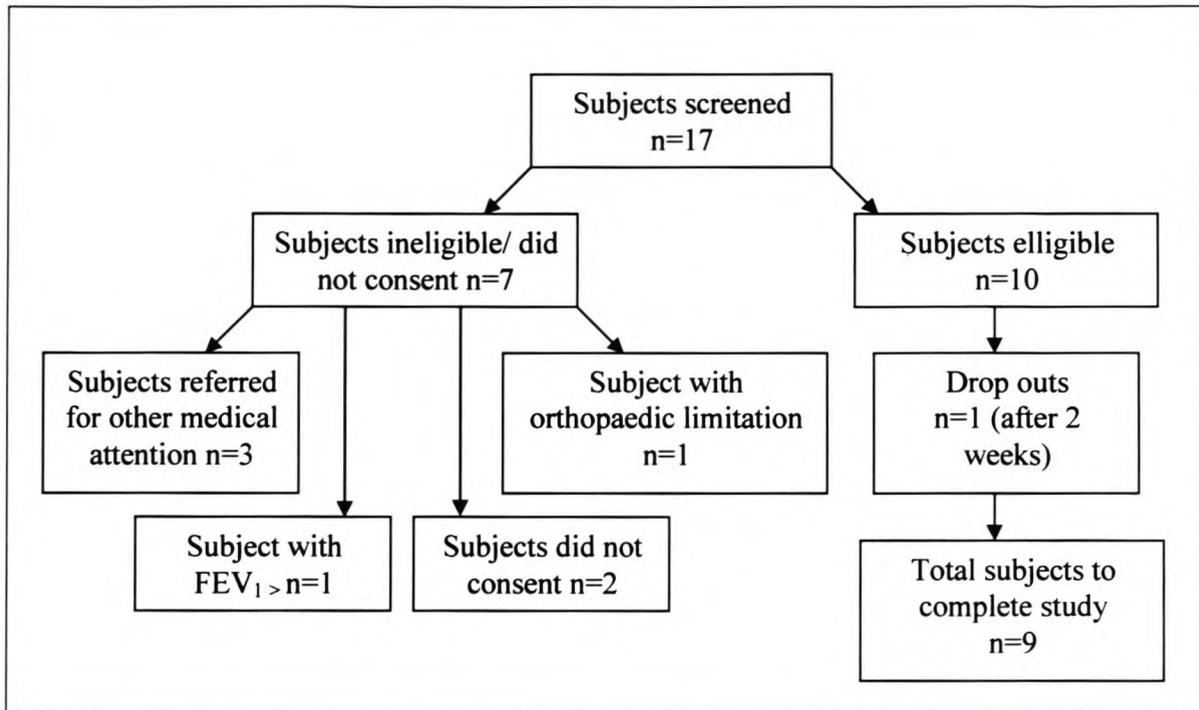


Figure 4.1. Subjects who dropped out, were ineligible and those who completed the intervention programme.

SUBJECT DEMOGRAPHICS

The study group consisted of nine subjects, five male subjects and four female subjects. At the onset of the study subjects' age ranged from 45 years old to 78 years old. The mean age was 67.78 years. All subjects were of Caucasian race. The minimum number of pack years was 16 and the maximum was 100. Three of the subjects were current smokers. Six of the subjects were in the third category (short of breath walking with others of similar age and physique, even on level ground, do own shopping) of the MRC dyspnea index, three subjects were a two (troubled by inclines or when hurrying on level ground) on the same index. Five subjects fell into the IIA category according to the GOLD COPD staging criteria. This meant that their FEV₁ was more than 50% but less than 80% of predicted, with or without symptoms. All subjects showed symptoms of COPD (cough, sputum production and dyspnea). Three subjects were in the category of IIB - their FEV₁ was more than 50% but less

than 80% of the predicted norm. One subject was a grade III (severe) COPD according to the GOLD disease staging criteria. This subject's FEV₁ was less than 30% of predicted. This particular subject was the only subject to use oxygen at home and while training. The patient demographics are shown below in *Table 4.1*.

Table 4.1. Patient Demographics

N.	Gender	Age	Race	Pack Years	MRC dyspnea index	Oxygen	GOLD COPD staging of severity
1.	Male	70	White	16	3	No	IIB: Severe
2.	Male	78	White	20	3	No	IIA: Moderate
3.	Female	76	White	54	2	No	IIA: Moderate
4.	Female	70	White	100	3	No	IIA: Moderate
5.	Male	45	White	50	2	No	IIB: Moderate
6.	Male	73	White	20	3	No	IIA: Moderate
7.	Female	78	White	90	3	Yes	III: Severe
8.	Male	64	White	46	3	No	IIA: Moderate
9.	Female	56	White	30	2	No	IIB: Moderate
Average		67.78		47.33	3		

RESULTS

Six-Minute Walk Test

The results of the 6MWT are shown in *Table 4.2*. The repeated measures ANOVA test demonstrated that subjects improved significantly on their 6MWT results ($p < 0.01$). Subjects' mean walking distance in six minutes improved from 390 m, in the first evaluation, to 500 m, on the second evaluation (see *Figure 4.2*). Thus on average, subjects improved their walking distance by 110 m. Eight out of nine subjects improved their walking distance

by more than the threshold of 54 m for noticeable change. Overall the intervention programme was successful in improving subjects' functional status.

Table 4.2. Results of the 6MWT

N.	1st evaluation	2nd evaluation	Difference
1.	320 m	420 m	100 m
2.	500 m	610 m	110 m
3.	320 m	420 m	100 m
4.	510 m	540 m	30 m
5.	510 m	610 m	100 m
6.	470 m	560 m	90 m
7.	120 m	320 m	200 m
8.	550 m	620 m	70 m
9.	200 m	420 m	220 m
Min.	120 m	620 m	30 m
Max.	550 m	620 m	220 m
Mean	388.89 m	502.22 m	113.33 m
Standard Deviation	154.79	109.18	

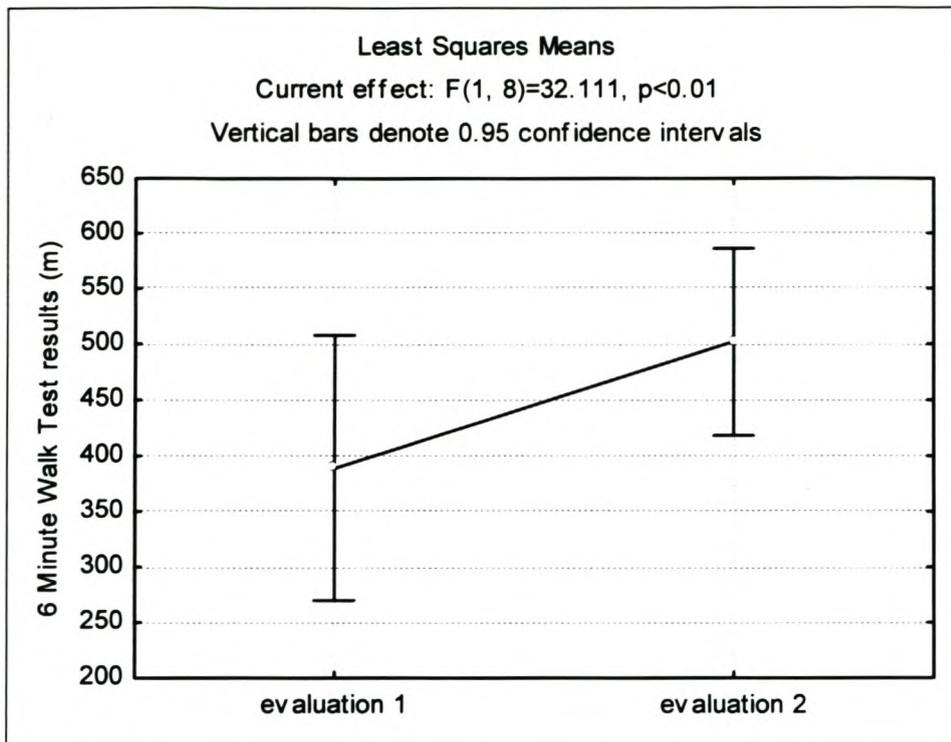


Figure 4.2. The difference in the mean distance walked by subjects in the 6MWT, pre- and post-intervention.

Baseline Dyspnea Index and Transitional Dyspnea Index

The single sample t-test was used to analyse the BDI and TDI. The TDI is a measure of change from the BDI. Results showed that the average subject improved by five out of nine, which is significantly higher than 0 ($p < 0.01$) (see Table 4.3). These results are highly significant ($p = 0,00003$). This means that a high proportion of the sample group experienced significant improvements in their levels of breathlessness after participating in the intervention programme. All subjects had a score greater than zero.

Table 4.3. Baseline and transitional dyspnea indices

	BDI	TDI
Minimum	3/12	+2/9
Maximum	8/12	+7/9
Mean	5/12	+5/9
Standard Deviation	1.98	1.51

St George's Respiratory Questionnaire

Results of the SGRQ are shown in *Table 4.4*. Analysis of the SGRQ showed a statistically significant change in the scores achieved by subjects on the SGRQ ($p = 0.03$) - although only marginally significant with 0.03 nearing the 5% significance level. The mean score changed from 54 (in the first evaluation) to 34 (in the second evaluation) out of 100 (see *Figure 4.3*). A decrease in the SGRQ score indicates an improvement in HRQL. One of the seven subjects measured had a positive change in her SGRQ score indicating a decrease in her HRQL compared with six subjects who scored significantly lowered SGRQ scores on the second evaluation compared to the first evaluation. The average subject decreased their initial evaluation's SGRQ score by 20 points. According to the ATS (2002b:no page number) this is a highly significant improvement in HRQL. The ATS (2002b:no page number) claims that any change by four or more units indicates effective treatment. The exercise programme is thus successful in improving COPD patients' HRQL.

Table 4.4. Results of the SGRQ

N.	1 st evaluation	2 nd evaluation	Difference
1.	-	-	-
2.	37.06	28.63	-8.43
3.	24.87	13.72	-11.15
4.	49.78	51.98	2.2
5.	61.41	27.86	-33.55
6.	41.57	27.15	-14.42
7.	65.82	51.21	-14.61
8.	57.33	-	-
9.	82.49	31.94	-50.55
Min.	24.87	13.72	2.2
Max.	82.49	51.98	-33.55
Mean	52.54	33.21	-18.64
Standard Deviation			

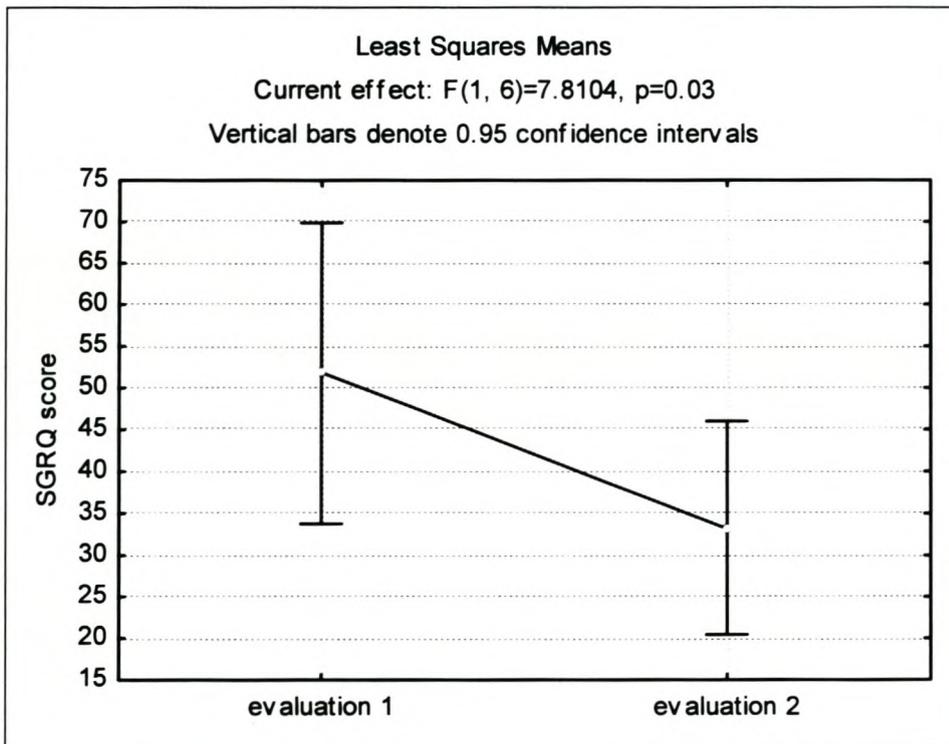


Figure 4.3. The difference in mean scores achieved by subjects on the SGRQ at pre- and post-intervention evaluations.

Forced Expiratory Volume in One Second

No significant changes were found in the subjects' lung function as was measured by the FEV₁. Results of subjects' FEV₁ are displayed in *Table 4.5*. The mean FEV₁, as a percent of the predicted value, stayed constant (see *Figure 4.4*) and the best value recorded for FEV₁ at the second evaluation decreased slightly, but not significantly (see *Figure 4.5*). The mean FEV₁ (absolute) decreased from 1.3 l to 1.2 l, a difference of 0.1 l. The largest change in absolute FEV₁ was a decrease of 0.59 l, from 2.05 l to 1.46 l (the reason for this large deterioration in lung function was not known). The largest change in FEV₁, as a percentage of predicted norms, was 29.75%, this was a subject who did not score well on other tests (this subject was also a smoker and was unmotivated). The largest increase in FEV₁ was by 0.24 l or by 8.99% as percentage of the subject's predicted norm.

Table 4.5. Results of absolute FEV₁ and percentage of predicted FEV₁.

N.	Absolute FEV ₁ (litres)			Percent of predicted FEV ₁ (%)		
	1 st evaluation	2 nd evaluation	Diff.	1 st evaluation	2 nd evaluation	Diff.
1.	0.96	0.78	-0.18	31.33	25.69	-5.64
2.	1.67	1.7	0.03	56.77	58.37	1.6
3.	0.95	1.19	1.24	57.31	66.3	8.99
4.	1.22	0.89	-0.33	67.94	38.19	-29.75
5.	1.74	1.26	-0.48	46.8	34.2	-12.6
6.	1.82	1.93	0.11	63.44	68.15	7.42
7.	0.59	0.77	0.18	28.28	37.55	-9.27
8.	2.05	1.46	0.59	61.06	75.08	-14.02
9.	0.71	0.82	0.11	32.75	37.97	-5.22
Min.	0.59	0.77	0.03	28.28	25.69	1.6
Max.	2.05	1.93	1.24	67.94	75.08	29.75
Mean	1.3	1.2	0.14	49.52	49.06	-6.9
Std Dev.	0.53	0.43		15.21	17.91	

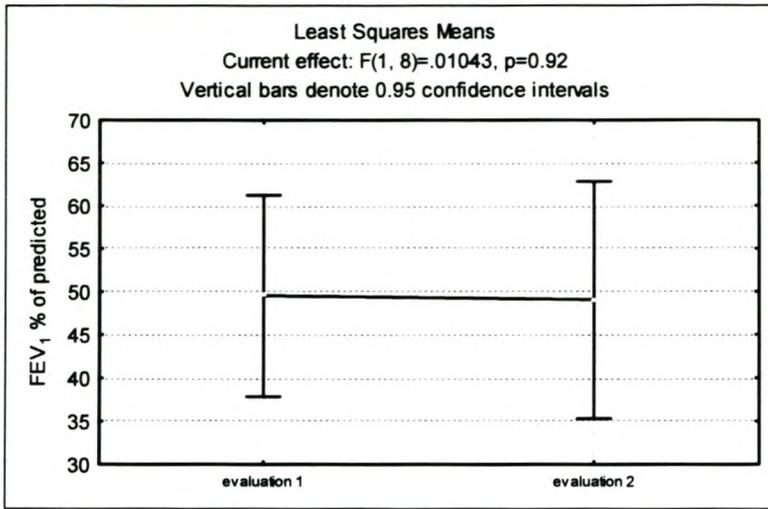


Figure 4.4. The difference in subjects' mean lung function (as noted by FEV₁ as a percentage of the predicted value) at pre- and post-intervention evaluations.

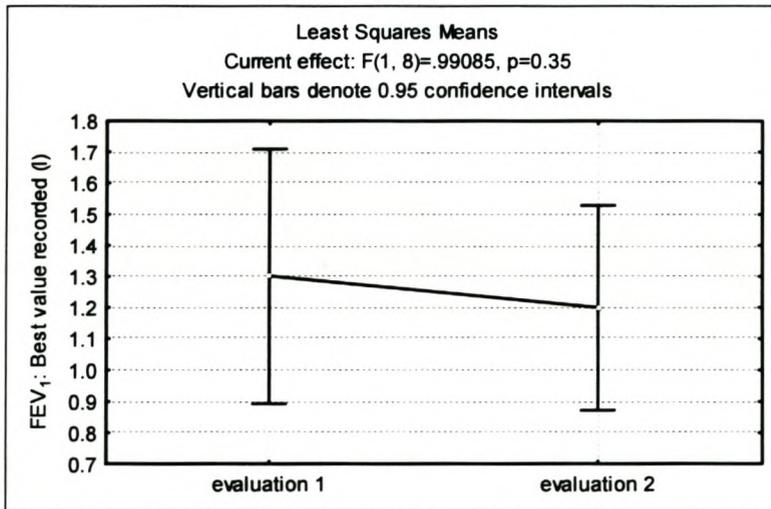


Figure 4.5. The difference in subjects' absolute mean lung function (as noted by the best FEV₁ measured at an evaluation) at the pre- compared to the post-intervention evaluation.

Patient Global Evaluation

Results of the patient global evaluation are shown in *Table 4.6*. The analysis showed a highly significant change in subjects' score in the second evaluation compared to the first evaluation ($p < 0.01$). Subjects' mean score improved from 45 to 66, a difference of 21 points (see *Figure 4.6*).

Table 4.6. Results of the patient global evaluation

N.	1st evaluation	2nd evaluation	Difference
1.	-	60	-
2.	40	65	25
3.	55	75	20
4.	70	85	15
5.	50	80	30
6.	30	45	15
7.	50	80	30
8.	30	40	10
9.	30	60	30
Min.	30	40	10
Max.	70	85	30
Mean	44.38	65.56	21.88
Standard Deviation	14.5	15.75	

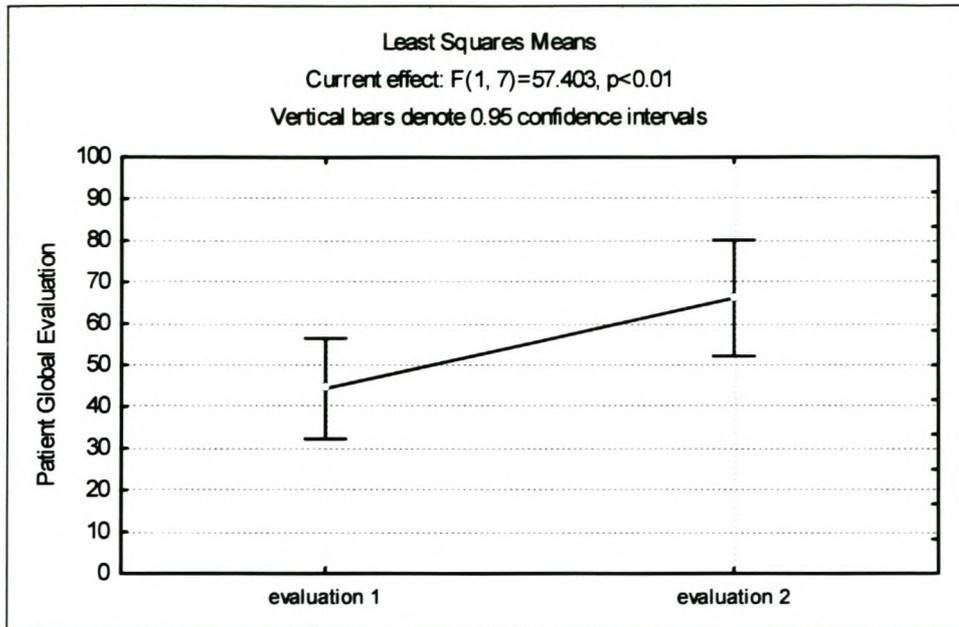


Figure 4.6. The difference in mean scores on the patient global evaluation at pre- compared to post-intervention evaluations.

Physician Global Evaluation

The results of the physician's global evaluation are displayed in *Table 4.7*. The physician's global evaluation showed a significant increase ($p < 0.01$). Subjects' mean score improved from 3.4, on the first evaluation, to 5.5, on the second evaluation (see *Figure 4.7*). The mean improvement was 2.1 on the physician's global score.

Table 4.7. Results of the physician global evaluation

N.	1st evaluation	2nd evaluation	Difference
1.	2	4	2
2.	-	5	-
3.	5	6	1
4.	2	5	3
5.	4	7	3
6.	5	6	1
7.	3	5	2
8.	2	6	4
9.	4	5	1
Min.	2	4	1
Max.	5	7	4
Mean	3.38	5.78	2.13
Standard Deviation	1.3	0.88	

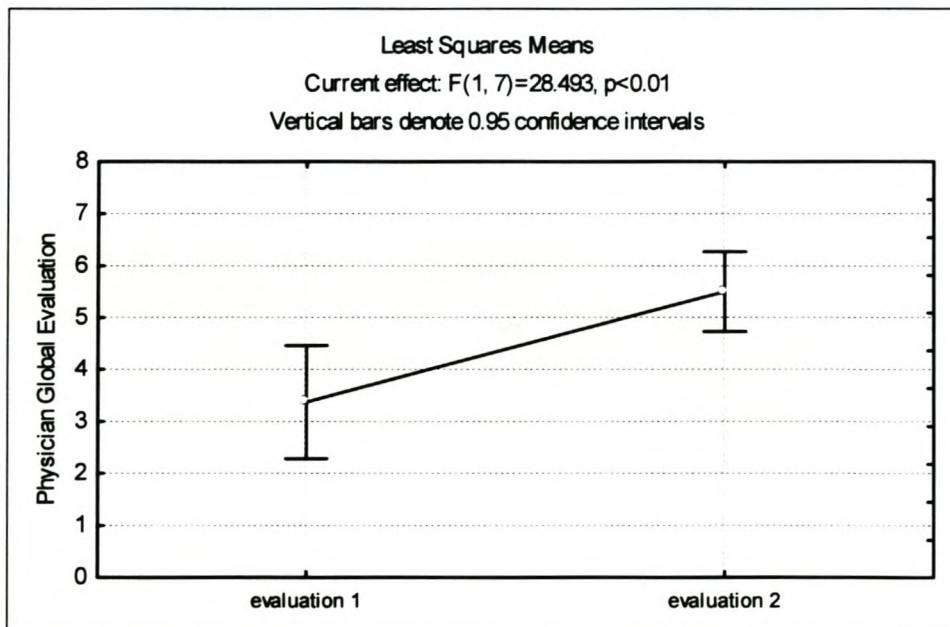


Figure 4.7. Graph showing the difference in mean scores on the physician global evaluation at pre- compared to post-intervention evaluations.

DISCUSSION

Subjects' functional status (6MWT), breathlessness (BDI and TDI), physician global evaluation and patient global evaluation improved significantly. All subjects experienced great improvements in their levels of breathlessness after participating in the intervention programme. However, it is unclear whether this improvement is due to subjects' desensitisation to increased levels of dyspnea or as a result of reduced oxygen demands by the working muscles after exercise training. The large improvements in the patient global evaluation means that subjects had enhanced perceptions of their current health status after exercise training. The increased physician's global evaluation scores means that the physician also rated the subjects' health as significantly better than it was before the rehabilitation programme.

Functional status improved largely in most subjects. A study by Berry *et al.*, (1999:1252) reported significant improvements in functional exercise capacity of severe, moderate and mild groups of COPD patients after their participation in an outpatient rehabilitation programme. Although Berry *et al.*, (1999:1252) differed from the present study in that the group with severe COPD made the smallest in gains, with the moderate group making more than twice the gains of the severe group. In the present study the largest increase in distance of the 6MWT was made by the subject with the most severe COPD. She improved by 200 m. The smallest improvement in functional status was measured in a subject who was a heavy smoker (40 cigarettes a day), she only increased her walking distance by 30 m compared to the sample group's average of 110 m. The same subject did not experience notable changes in HRQL when compared to the rest of the sample group who experienced much larger improvements. Bendstrup *et al.*, (1997:2805) found a large improvement in COPD subjects' 6MWT of 113.1 ± 10.4 (mean \pm standard error of the mean) metres after 12 weeks of pulmonary rehabilitation, "which is larger than the improvements reported in other studies" (Bendstrup *et al.*, 1997:2805). The average increase in 6MWT in the present study was 110 m which is close to the good results recorded by Bendstrup *et al.*, (1997:2805).

Although there was not a large statistical difference in the SGRQ, the test is known to be very sensitive to changes in COPD patients' HRQL and a small change in patients' score indicates noticeable change in HRQL. Thus the statistically significant change in SGRQ represents a significant improvement in subjects' HRQL. A recent study by Brooks *et al.*, (2002:21) found a 35% improvement of HRQL post-rehabilitation as was measured by the SGRQ and the chronic respiratory disease questionnaire (CRDQ). The results of the present study's SGRQ improved by an average of 20% which indicates that there is a need to adjust the intervention programme in order to gain the improvements that were proven possible by Brooks *et al.*, (2002:21). Insignificant changes in HRQL from the baseline to the follow-up evaluation were recorded by Berry *et al.*, (1999:1250). Berry *et al.*, (1999:1251) mention that:

“these results are unique in that previous studies have shown pulmonary rehabilitation, which includes exercise training, to result in improvements in physical performance and health-related quality of life primarily in patients with moderate or severe disease but not mild disease.”

The SGRQ scores were not measured for subjects one and eight due to communication errors between the study leaders. However, the significant improvement of these subjects' 6MWT, dyspnea indices, patient global and physician global scores indicated an improvement in their overall health status which can be assumed to have significantly improved their HRQL.

Subjects' lung function did not change significantly. In fact there was a slight decrease in the mean FEV₁. There is “general consensus that airflow and gas exchange are not enhanced by pulmonary rehabilitation” (Holden *et al.*, 1990:332). The lowered lung function values in this study may be as a result of the progressive nature of COPD where there is a constant deterioration of the lungs.

Body composition (BMI) did not change significantly after the rehabilitation programme. In fact there was a slight decrease in the mean BMI. The average subject's BMI fell into the category of ‘overweight’ – according to the ACSM (2000: 64). The reduction in overweight subjects' BMI reduced their risk of obesity related diseases. Schols *et al.*, (1991:695)

concluded that the measurement of fat free mass is an important determinant of exercise performance in patients with COPD. The present study, however, did not find a high correlation between subjects' BMI and the distance they walked in the 6MWT.

CONCLUSION

Exercise in pulmonary rehabilitation is successful in improving COPD patients' functional status. Exercise is also successful in improving COPD patients' levels of dyspnea, patients' perception of their own health and the physician's perception of COPD patients' health. Exercise does not change lung function in COPD patients although pulmonary rehabilitation improves COPD patients' HRQL. In this study group BMI remained relatively constant on average. Nutritional counseling is likely to complement exercise in the optimal management of body mass in COPD patients. Overall the results in this study came to similar conclusions as research in the past did. No study of this kind has previously been published in South Africa. This research has confirmed that pulmonary rehabilitation can be successfully applied to COPD patients in South Africa and potentially other developing countries too. Pulmonary rehabilitation in South Africa can achieve similar benefits to those derived from pulmonary rehabilitation in the United States of America and in the United Kingdom.

CHAPTER FIVE: CONCLUSIONS

RESEARCH CONCLUSION

Exercise has multiple benefits for COPD patients. Exercise improves COPD patients' quality of life and their ability to perform activities of daily life. The importance of COPD patients' quality of life cannot be overemphasized. COPD is incurable and thus patients' focus is on enhancing their remaining years of life. Currently medicine has only limited capacity to improve the symptoms of COPD. Exercise complements medical treatment and gives COPD sufferers an opportunity to enhance their ability to live each day to its fullest. Past research in other countries had similar findings and now exercise has demonstrated to be a successful component of pulmonary rehabilitation in South Africa too.

The success of the intervention programme suggests that these exercises should be included in future pulmonary rehabilitation programmes. Pulmonary rehabilitation should consist of aerobic exercise, walking (preferably) or cycling, at an intensity of 60 – 75% of maximum heart rate for the duration of 20 – 30 minutes. Celli (2003a:no page number), the ATS (1999:1672) and Maltais *et al.*, (1997:557) also agreed upon walking as a form of aerobic exercise as walking is necessary for most daily activities. Aerobic exercise may be continuous or intermittent - depending on the subject's exercise capacity. Clark (1994:276), Mink (1997:no page number) and Cooper (2001:S671) were also in favour of the accumulation of 20-30 minutes of aerobic exercise. The ATS (1999:1672) also found substantial benefits after COPD patients exercised at the same intensity (60-75% of maximum heart rate) as the subjects in this study did. Strength training of the arms, legs and abdominal muscles should be performed with one to three sets of 10 repetitions. An intensity of four to six on the Modified Borg Scale should be used in strength training of COPD patients, as was also successfully used in a study by Maltais *et al.*, (1997:561). During the intervention programme it was noticed by the study leaders that subjects experienced reduced heart rate and breathlessness for the same resistance exercises at similar work intensities. Study leaders

also noted that all subjects increased the weight of resistance and/or the number of repetitions performed during the 12 weeks of exercise. Strength gains and reduced heart rate at similar work intensities were not measured objectively but there was definitely a noticeable improvement in all subjects. The improvement of arm strength is thought to have contributed to subjects' enhanced ability to perform ADL's and an improved HRQL. The improved leg strength is thought to have contributed to subjects' functional status and reduced dyspnea during activities such as climbing stairs or walking uphill. Abdominal strength is related to breathing efficiency, especially the *Tranverse Abdominus* muscle (which was focused upon). Improved abdominal strength is theorised to enhance COPD patients' ability to inspire and expire to fuller lung capacities. The *Sternocleidomastoid* muscle plays an important role in inspiration at high lung capacities. Exercise three times a week in this study elicited positive results. The optimal number of exercise sessions per week was confirmed in studies done by Mink (1997:no page number), Ringbaek *et al.*, (2000:153) and Cooper (2001:S671). Overall the exercise programme was successful but this cannot be attributed to one particular exercise or another. It can only be supposed that the success of the programme is attributed to the combination of all the exercises. Further research needs to be done to clarify the role of each exercise.

The use of medication seemed to decrease after pulmonary rehabilitation. This was not a variable that was objectively measured, but study leaders noticed that all subjects commented on their reduced use of a bronchodilator in an average day and also that they did not need to use cortisone as frequently as before. A few subjects said that they did not visit their doctor as often as they had in the past and some subjects did not experience as many acute exacerbations as they had in the past. This means that pulmonary rehabilitation has the potential to reduce medical expenses and medical aid claims. The reduction in medical expenses after pulmonary rehabilitation has been established in studies in countries other than South Africa. The study did not scientifically investigated whether there is a reduction in medical expenses but it was definitely a benefit that was mentioned by subjects on many occasions throughout the intervention programme. It is recommended that two aspects of pulmonary rehabilitation (doctor's visits and medication use) be objectively measured in future studies of this nature in South Africa. Pulmonary rehabilitation has the potential to be a

relatively inexpensive method of improving the HRQL and reducing the expenses of South African COPD patients in a nation who can scarcely afford the medical attention required for the optimal treatment of chronic illnesses.

Pulmonary rehabilitation is not practiced scientifically and in most cases it is not offered to patients by specialists and general practitioners in South Africa. This study has shown that COPD patients' participation in specially designed exercise programmes results in an improvement in their QOL and functional status. It is thus important that doctors, biokineticists and physiotherapists around our country be educated as to the benefits that pulmonary rehabilitation has to offer. Patients need to be encouraged to join pulmonary rehabilitation programmes by their physicians and doctors. Pulmonary rehabilitation programmes need to be set up around the country where they are easily accessible for patients, for example, in clinics, hospitals and gyms. It is thus important that the medical society of South Africa be made aware of the current under-utilization of pulmonary rehabilitation and its vast potential benefits. Specialists, general practitioners, physiotherapists and biokineticists need to work as a team towards the more holistic and more effective treatment of COPD patients in South Africa.

LIMITATIONS

In retrospect it was found that there were a number of errors in the research procedures. A potential source of error may have been the inconsistency of subjects' use of a bronchodilator. At the first evaluation, subjects' lung function was tested pre- and post-bronchodilator in order to exclude the diagnoses of asthma. This meant that each subject received a bronchodilator approximately 15 minutes before the 6MWT. At the second evaluation, however, there was no regulation of the use of a bronchodilator as the need for diagnosis no longer existed. This meant that subjects most likely had used a bronchodilator for their morning dose and could have used a bronchodilator at any other (unrecorded) time before the performance of the exercise test at the second evaluation. It is only known that subjects did not use a bronchodilator within 15 minutes prior to exercise test of the second evaluation.

The use of a bronchodilator 15 minutes before the pre-intervention 6MWT was likely to have caused a slightly enhanced walking distance whereas the identical bronchodilator-enhanced performance was not established during the post-intervention evaluation. Thus subjects underachieved in the second walking test compared with the first. However, this error was indeed a positive error as any improvement seen in the exercise test result was over and above the bronchodilator-enhanced performance of the first evaluation. Thus the performance improvements were underestimated rather than overestimated.

Subjects' daily routines were unmonitored throughout this study. It is possible that changes in subjects' daily routines may have positively or negatively affected their performance in the study. Abruptions in subjects' daily lives may have affected their ability to attend exercise sessions or caused subjects to be more tired, for example. Positive changes in subjects' daily routines may have included improved sleeping habits and an increased appetite which would have had a positive influence on their exercise performance. Subjects were asked by study leaders to avoid significant changes in their daily routines for the duration of the study. Unfortunately it was not practical to control this completely for as long as 12 weeks when working with patients on an out-patient basis.

Six exercise sessions of absence resulted in the exclusion of a subject from the study. In a few cases, however, subjects were unable to avoid being absent from exercise sessions due to acute exacerbations and other complications. In retrospect, the set number of six sessions was not enough for the subjects who were in the later stages of COPD. This is a topic that needs some more thought for future research in the same field.

Limitations occurred that were beyond the control of the study supervisors. One limitation was the restricted times within which subjects could be tested. The other limitation related to the availability of subjects who were to be tested. The intervention programme was three months long so it meant that the entire data collection was stretched over a relatively long time and thus a time limit was necessary for the study. Consequently the total number of subjects in the study was fewer than hoped.

The second evaluation was delayed in three cases for different reasons. One subject's second evaluation was delayed by two weeks due to a fall she took which resulted in a severe haematoma on her right knee. Her results, however, still showed a significant improvement when compared to her first evaluation's results. The second subject delayed the second evaluation by a week due to his vacation which extended over the date set for the second evaluation. Another subject's test date was postponed by a week as he was suffering from a chest infection at the time of the test date.

The fact that three of the subjects continued to smoke throughout the study was likely to have had a significant effect on their results and the results of the study as a whole. It is most likely that these subjects would have displayed increased improvements in their post-intervention scores versus their pre-intervention scores had they been non-smokers. Due to smokers being included in the study the subject group was not entirely uniform. However, both smokers and non-smokers experienced improved results therefore the exercise programme can successfully be applied to both groups of COPD patients.

FUTURE RESEARCH AND RECOMMENDATIONS

Home pulmonary rehabilitation is a topic in need of research in South Africa. The benefits of pulmonary rehabilitation are many but home rehabilitation has potential to benefit COPD patients even further. Home rehabilitation is likely to be preferred since it is more convenient for the patients and patients can apply their training in daily life. Busch and McClements (1988:469) feel that if a home-based exercise programme can be shown to effectively reduce disability of patients with COPD, the benefits will be more accessible to more patients. According to Busch and McClement (1988:469) the cost of delivering a home-based exercise programme is also far less than a hospital-based exercise programme. Research needs to be done to determine the feasibility of home pulmonary rehabilitation in South Africa.

“Adherence is often a major problem for the patient with COPD” (Hodgkin *et al.*, 1993:90). Ketelaars *et al.*, (1997:366) found in their study that COPD patients tended to revert to their pre-rehabilitation sedentary lifestyles in the months following rehabilitation and according to Celli (1999:196), the effect achieved by training is lost after the exercise is stopped. Brooks *et al.*, (2002:20) state that: “poor adherence has a detrimental effect on morbidity, mortality and healthcare resources”. According to Hodgkin *et al.*, (1993:90) remarkably few studies have evaluated methods to improve the adherence of COPD patients to an exercise programme. Research needs to be performed to determine the most effective means of encouraging COPD patients to adhere to pulmonary rehabilitation programmes.

It is suggested that COPD patients who are smokers be excluded from studies or placed in their own separate experiment group. This is because smokers do not achieve the same benefits from therapy as non-smokers and it is possible that smokers will skew the data incorrectly with their extreme test results.

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APPENDICES

APPENDIX ONE: PATIENT INFORMATION AND CONSENT FORM

PATIENT INFORMATION AND CONSENT FORM

The influence of pulmonary rehabilitation on the quality of life and exercise capacity of patients with chronic obstructive pulmonary disease (COPD).

You are invited to participate in a research study which will determine the influence of a rehabilitation programme on your quality of life and exercise capacity. The evaluations and the rehabilitation process will be monitored and managed by professional persons.

You are aware that you suffer from chronic obstructive pulmonary disease (COPD) and that your exercise capacity is limited. This is the reason you are requested to participate in this study. It is important that you understand the reasons for the study and that you address all your relevant questions to the doctor in charge. You are asked to inform your personal physician of your participation in the study.

Aim of the Study

The condition known as COPD is an inflammatory condition of the airways which is commonly noted by a wheeze and breathlessness. As a result of the breathlessness your exercise capacity is limited and this leads to weakening of your muscles, especially of your thighs. These muscle groups as well as the upper arm muscles must function in the absence of complete oxygenation and thus they weaken continuously. This weakening limits you with regards to everyday functioning and pleasure activities in which you would like to participate.

The aim of the rehabilitation process is to strengthen these muscle groups and hereby improve your exercise capacity - even though your lung function may not necessarily improve. The rehabilitation programme will take place over 12 weeks on three of the five working days in a week. Rehabilitation will take place under strict monitoring of Ms Jenny Brown, who will encourage and motivate you to adhere to the programme. Smokers are not excluded from the study, but they will be strongly encouraged to join a stopping-smoking programme offered by Prof. Bollinger in the Medical Faculty. The study will be performed according to international standards for medical research as is determined by the ICH guidelines for good clinical practice and the statement of Helsinki.

Ratification of the project will be gained from the Ethics Committee of the Faculty of Health Sciences of Stellenbosch University.

Requirements for Participation

Symptomatic COPD patients who have grade I and II levels of breathlessness according to the SATS (South African Thoracic Society) will be allowed to participate. The grade of your sickness will be determined by a lung-function test, a six-minute walking test and measurements of your body mass relative to your height. If you are being treated with oxygen at home and you significantly desaturate, in other words the saturation of oxygen in your blood decreases, during the exercise, you will be required to train during the exercise programme while using oxygen. If you show significant signs of right heart failure or if you have left and right heart failure, you will be referred to your physician for treatment before the rehabilitation programme can begin. Thus you remain in the care of your own physician. Your physician's input with regards to acute exacerbations, hospitalizations and changes in your treatment will form an essential part of the study. You are required to have transport to the Department of Sport Science, Stellenbosch University and be contactable via telephone.

Evaluation Day 1

You will arrive according to appointment at Prof. JR Joubert's consulting rooms at 7 Rattray Lane, Stellenbosch. The consent form will be discussed with you and you will be given the opportunity to sign your consent once you have been given the opportunity to ask any questions. You will be given a clinical evaluation after which a standard inspiratory and expiratory lung function test and ECG (heart evaluation) will be performed. In the procedure you will have to blow into a lung function apparatus. A six-minute walking test will be performed which you will do with encouragement from a technologist. Your oxygen levels and pulse will be monitored during the test. You may do the walk test by walking a little and resting and walking and resting etc for the duration of the six minutes, it will be done within your exercise capacity. The grade of your sickness will be discussed according to the points system of the SATS's guidelines for COPD. General tips with regards to the disease, the presence of complications i.e acute exacerbations, the steps that will be taken, and your communication with your physician, will be discussed.

Rehabilitation Programme

You will report to the Department of Sport Science, Coetzenberg, to meet with Ms Jenny Brown by appointment. The rehabilitation process will be explained and demonstrated to you. A questionnaire called the St George's Respiratory Questionnaire, will be completed which will confirm your quality of life and the extent of your limitations based on your history. You will participate in the rehabilitation programme individually or within a group. The exercise programme will be on three of five week days and will last a minimum of 12 weeks. Each session will last approximately one hour. You will be excluded from the study if you are unable to participate in the 12-week programme uninterrupted. Your presence at the rehabilitation programme (according to appointment) is very important and your participation in the study will be ended if you cannot attend more than six of the

appointments. Goals will be set and you will be encouraged to reach them. The exercise programme will be adjusted according to the extent of your limitations. Your progress will be determined from your own baseline exercise capacity and you are not competing with anyone else in your group. The exercise programme consists of walking exercises and muscle strengthening with the help of biokinetic apparatus. As each patient joins the programme they will be divided into two groups. The one group will be given a home programme, about which they will be required to write a weekly report. The second group will follow their normal home programme. The aim of this is to be able evaluate the patients again six months after the exercise programme has ended in order to determine how many individuals in the group were able to maintain their fitness level. If you suffer a temporary exacerbation of your disease symptoms, you will not participate in your daily exercise programme and you will be asked to consult your physician for a re-evaluation.

Evaluation Day 2

After completion of the 12-week rehabilitation programme you will again complete the St. George's Respiratory Questionnaire in order to measure your progress with regards to your quality of life.

According to appointment you will report to the practice of Prof. Joubert. The lung function test (inspiration and expiration test), six-minute walk test, your grade of dyspnea you're your body mass relative to your height will be measured again.

Evaluation Day 3

You will report again by appointment at Prof. Joubert's consulting rooms. The evaluation that was performed initially will be repeated and the lung function test, the six-minute walk test and grading of dyspnea will be repeated. Your body mass relative to your height will be

measured again. Hereby your progress in the programme will be determined. You will be referred back to your physician who will follow-up on your disease symptoms, acute exacerbations and hospitalizations over the last six months.

PATIENT CONSENT FORM

The information above is explained to me (name of relevant person) in a language I am fluent in. I have been given the opportunity to ask all questions and all questions have been satisfactorily answered.

There has been no pressure placed on me to agree to participate and I understand that I may stop with the programme without any penalisation.

Participation in the project does not hold any additional costs.

I AGREE TO PARTICIPATE IN THE ABOVE MENTIONED PROJECT

**Signed /confirmed at On
of20.....**

.....

Patient signature

.....

Witness signature

DECLARATION BY RESEARCHER

I declare that

- I explained the information content of this document to
.....(name of participant/ patient).
- I encouraged her/him and gave her/him sufficient time to address me with any queries.
- This conversation took place in English/Afrikaans and no translator was used.

Signed at on 20.....

.....
Signature of researcher/ researcher's representative

.....
Signature of Witness

APPENDIX TWO: BASELINE DYSPNEA INDEX**Functional Impairment**

- _____ Grade 4: **No Impairment.** Able to carry out usual activities and occupation without shortness of breath
- _____ Grade 3: **Slight Impairment.** Distinct impairment in at least one activity but no activities completely abandoned. Reduction in activity at work or in usual activities that seems slight or not clearly caused by shortness of breath.
- _____ Grade 2: **Moderate Impairment.** Patient has changed jobs *and/or* has abandoned at least one usual activity due to shortness of breath.
- _____ Grade 1: **Severe Impairment.** Patient unable to work *or* given up most *or* all customary activities due to shortness of breath.
- _____ Grade 0: **Very Severe Impairment.** Unable to work *and* has given up most or all customary activities due to shortness of breath.
- _____ W: **Amount uncertain.** Patient is impaired due to shortness of breath, but amount cannot be specified. Details are not sufficient to allow impairment to be categorized.
- _____ X: **Unknown.** Information unavailable regarding impairment.
- _____ Y: **Impaired for Reasons Other than Shortness of Breath.** For example, musculoskeletal problem or chest pain.

Magnitude of Task

- _____ Grade 4: **Extraordinary.** Becomes short of breath only with extraordinary activity, such as carrying heavy loads on the level, lighter loads uphill, or running. No shortness of breath with ordinary tasks.
- _____ Grade 3: **Major.** Becomes short of breath only with such major activities as walking up a steep hill, climbing more than three flights of stairs, or carrying a moderate load on the level.

- _____ Grade 2: **Moderate.** Becomes short of breath with moderate or average tasks, such as walking up a gradual hill, climbing less than three flights of stairs, or carrying a light load on the level.
- _____ Grade 1: **Light.** Becomes short of breath with light activities, such as walking on the level, washing, standing or shopping.
- _____ Grade 0: **No Task.** Becomes short of breath at rest, while sitting, or lying down.
- _____ W: **Amount Uncertain.** Patient has limited exertional capacity due to shortness of breath, but amount cannot be specified. Details are not sufficient to allow impairment to be categorised.
- _____ X: **Unknown.** Information unavailable regarding limitation of magnitude of task.
- _____ Y: **Impaired for Reasons Other than Shortness of Breath.** For example, musculoskeletal problem or chest pain.

Magnitude of Effort

- _____ Grade 4: **Extraordinary.** Becomes short of breath only with the greatest imaginable effort. No shortness of breath with ordinary effort.
- _____ Grade 3: **Major.** Becomes short of breath with effort distinctly submaximal, but of major proportion. Tasks performed without pause unless the task requires extraordinary effort that may be performed with pauses.
- _____ Grade 2: **Moderate.** Becomes short of breath with moderate effort. Tasks performed with occasional pauses and requiring longer to complete than the average person.
- _____ Grade 1: **Light.** Becomes short of breath with little effort. Tasks performed with little effort or more difficult tasks with frequent pauses and requiring 50 to 100 percent longer to complete than the average person might require.
- _____ Grade 0: **No Effort.** Becomes short of breath at rest while sitting, or lying down.

- _____ W: **Amount Uncertain.** Patient has limited exertional capacity due to shortness of breath, but amount cannot be specified. Details not sufficient to allow impairment to be categorised.
- _____ X: **Unknown.** Information unavailable regarding limitation of effort.
- _____ Y: **Impaired for Reasons Other than Shortness of Breath.** For example, musculoskeletal problem or chest pain.

(Mahler *et al.*, 1984)

WORKSHEET TO BE USED FOR ASSESSMENT OF DYSPNEA

Dyspnea Recordings:		Date:	Patient's Initials:
	FUNCTIONAL IMPAIRMENT	MAGNITUDE OF TASK	MAGNITUDE OF EFFORT
Job			
Housework, shopping			
Leisure Activities, Gardening			
Social Activities			
Washing/ Dressing			
At Rest			
Any Other			
BDI Score: 0-4	Functional Impairment:	Magnitude of Task:	Magnitude of Effort:

TOTAL:**/12**

APPENDIX THREE: TRANSITION DYSPNEA INDEX**Change in Functional Impairment**

- _____ -3: **Major Deterioration.** Formerly working and has had to stop working and has completely abandoned some of the usual activities due to shortness of breath.
- _____ -2: **Moderate Deterioration.** Formerly working and has had to stop working or has completely abandoned some of usual activities due to shortness of breath.
- _____ -1: **Minor Deterioration.** Has changed to a lighter job and/or has reduced activities in number or duration due to shortness of breath. Any deterioration less than preceding categories.
- _____ 0: **No Change.** No change in functional status due to shortness of breath.
- _____ +1: **Minor Improvement.** Able to return to work at reduced pace or has resumed some customary activities with more vigour than previously due to improvement in shortness of breath.
- _____ +2: **Moderate Improvement.** Able to return to work at former pace and/or able to return to most activities with moderate restriction only.
- _____ +3 **Major Improvement.** Able to return to work at former pace and able to return to full activities with only mild restriction due to improvement of shortness of breath.
- _____ Z: **Further Impairment for Reasons Other than Shortness of Breath.** Patient has stopped working, reduced work, or has given up or reduced other activities for other reasons. For example, other medical problems, being “laid off” from work, etc.

Change in Magnitude of Task

- _____ -3: **Major Deterioration.** Has deteriorated two grades or greater from baseline status.
- _____ -2: **Moderate Deterioration.** Has deteriorated at least one grade but less than two grades from baseline.
- _____ -1: **Minor Deterioration.** Has deteriorated less than one grade from baseline. Patient with distinct deterioration within grade, but has not changed grades,
- _____ 0: **No Change.** No change from baseline.
- _____ +1: **Minor Improvement.** Has improved less than one grade from baseline. Patient with distinct improvement within grade, but has not changed grades.
- _____ +2: **Moderate Improvement.** Has improved at least one grade but less than two grades from baseline.
- _____ +3: **Major Improvement.** Has improved two grades or greater from baseline.
- _____ Z: **Further Impairment for Reasons Other than Shortness of Breath.** Patient has reduced exertional capacity, but not related to shortness of breath. For example, musculoskeletal problem or chest pain.

Change in Magnitude of Effort

- _____ -3: **Major Deterioration.** Severe decrease in effort from baseline to avoid shortness of breath. Activities now take 50-100% longer to complete than required at baseline.
- _____ -2: **Moderate Deterioration.** Some decrease in effort to avoid shortness of breath, although not as great as preceding category. There is greater pausing with some activities.

- _____ -1: **Minor Deterioration.** Does not require more pauses to avoid shortness of breath, but does things with distinctly less effort than previously to avoid breathlessness.
- _____ 0: **No Change.** No change in effort to avoid shortness of breath.
- _____ +1: **Minor Improvement.** Able to do things with distinctly greater effort without shortness of breath. For example, may be able to carry out tasks somewhat more rapidly than previously.
- _____ +2: **Moderate Improvement.** Able to do things with fewer pauses and distinctly greater effort without shortness of breath. Improvement is greater than preceding category, but not of major proportion
- _____ +3: **Major Improvement.** Able to do things with much greater effort than previously with few, if any, pauses. For example, activities may be performed 50-100% more rapidly than at baseline.
- _____ Z: **Further Impairment for Reasons Other than Shortness of Breath.** Patient has reduced exertional capacity, but not related to shortness of breath. For example, musculoskeletal problem or chest pain.

(Mahler *et al.*, 1984)

WORKSHEET FOR ASSESSMENT OF DYSPNEA

Transitional Dyspnea Index (TDI)

Dyspnea Recordings:		Date:	Patient's Initials:
	FUNCTIONAL IMPAIRMENT	MAGNITUDE OF TASK	MAGNITUDE OF EFFORT
Job			
Housework, shopping			
Leisure Activities			
Social Activities			
Washing/ Dressing			
At Rest			
Any Other			
TDI Score: -3 - +3	Functional Impairment:	Magnitude of Task:	Magnitude of Effort:

TOTAL: /-9 - +9

Instructions for Administration of the Baseline and Transition Dyspnea Index

The objective of the Baseline and Transition Dyspnea Indexes is to measure the severity of breathlessness (sensation of breathlessness, shortness of breath) in symptomatic patients. The Baseline Dyspnea Index (BDI) measures the severity of dyspnea at the beginning of a trial and the Transition Dyspnea Index (TDI) evaluates changes from this baseline (transition period). The test is applicable to patients with dyspnea on exertion or at rest due to respiratory disease. Administration of the Index should be undertaken before any lung physiologic measurements on the test day and the interviewer must be blinded to other parameters evaluated for this patient.

The Dyspnea Indices were devised such that grading breathlessness could be performed as part of obtaining a history from the patient. The indices include the categories Functional Impairment, as well as Magnitude of Task and Magnitude of Effort which provokes breathlessness. The interviewer asks specific questions based on the criteria of the various grades of impairment or change in the mentioned categories. This approach was selected instead of a questionnaire answered by the patient himself in order to allow an interviewer with medical training or background to grade breathlessness in a simple and brief encounter.

The BDI as well as the TDI are composed of the three categories mentioned. The BDI includes five grades of severity from zero (severe) to four (unimpaired) and the categories are summed to create the focal score (zero to twelve). The TDI ranges from minus three (major deterioration) to plus three (major improvement) including a zero score to indicate "no change". Also for the TDI the three categories are added to obtain a focal score ranging from minus nine, including zero, to plus nine. Provision is made for circumstances when dyspnea cannot be rated: in the BDI, score "W" if no information, or "Y" if the patient's capacity is compromised by factors other than respiratory. In the TDI, score "Z" if reduction of activities, effort or functional impairment is caused by reasons other than respiratory.

An interviewer, who should be experienced in history taking for respiratory disease, administers the test. The interviewer should be a physician, nurse, respiratory therapist, cardiopulmonary technician or have similar qualification with advanced knowledge or training concerning dyspnea in respiratory disease. Evaluation and scoring is performed during the interview and needs the same level of experience. It is preferred that the same person conducts all evaluations for each patient.

The initial question addressed to the subject should be “Do you experience shortness of breath?” If the subject answers “No”, then the interviewer should ask whether any physical activities cause the subject to experience breathlessness. If the answer to the questions is “Yes”, then additional questions follow to achieve the specific grading. Questions concerning the patient’s shortness of breath should be open-ended, and concentrate on how the shortness of breath affects his/her daily life, e.g. the maintenance or upkeep of residence, gardening, or shopping. The interviewer should focus on the specific criteria for the severity of breathlessness as specified in the indices and the patient should be rated based on the responses to the questions. The interviewer circles one answer in the index that best describes how the patient’s daily activities are affected by his/her respiratory disease.

The interview process at each visit (baseline and follow up) should not take longer than five minutes.

At the Baseline Visit (BDI)

Functional Impairment:

The first component focuses on finding out which types of everyday life functions at home or in his/her job the patient is still able to perform. Are there any activities that he has had to give up or change due to his shortness of breath compared to the level of activity before the onset of his respiratory disease? (e.g. can he/she mow the lawn or do house work, can he/she climb the stairs to the office or apartment as previously, can he/she walk uphill or

cycle as previously, can he/she do the shopping, can he/she dress him/herself, can he/she care for the pet?). It is important that the interviewer takes notes of the types of activities and the attached form may serve as an example (not part of the CRF) of a record of the identified events that can be referred to at follow up visits for the TDI. Circle the grade of impairment in the BDI.

Magnitude of Task:

The second component focuses on the level and extent to which the individual tasks can be performed until breathlessness is noticed. Again, it is important to record the level in the form to be able to compare at follow up visits. Ask which activities make the patient feel breathless (e.g. to what extent can he/she do the daily household chores, can he/she mow 30sqm lawn or how large is it, can he/she cycle on ground level, gentle slopes uphill, moderate slopes uphill, which distance can he/she walk). Provide the examples of the various grades and then circle a grade for magnitude of task.

Magnitude of Effort:

The third component focuses on the level of effort (exertion, vigour) that can be invested to perform the individual tasks. Again allude to individual tasks and define the effort that makes a patient feel breathless (e.g. shortness of breath only with extraordinary effort when mowing the lawn, or can just be done at normal pace, or can do it very slowly, or need many pauses, can do the house work as rapidly as usual, or takes much longer than previously, or need many pauses). Again, it is important to take notes of examples and patient's description to be able to assess changes at follow up visits. Provide the examples of the various grades for the magnitude of effort from the index and circle one.

At Follow-up Visits (TDI)

The TDI measures change from the baseline state in the three categories. The interviewer refers to his records of the individual patient's reported activities that result in breathlessness, their magnitude of the task required to evoke breathlessness, and the effort of performance possible. The record sheet and grades from the BDI serve as references and for reminding the interviewer as well as the patient of his/her selections before selecting a grade from the TDI. At each follow up visit the interviewer refers back to the BDI and his original records and not to the previous TDI.

Change in Functional Impairment:

Review with the patient his/her functional status and the types of activities performed as recorded at baseline. Ask the patient if there are any changes or modifications in his/her activities since the baseline visit (e.g. has he/she given up or taken on activities). Select a score from the index based on these changes, or circle zero if unchanged.

Magnitude of Task:

Review the level, i.e. magnitude of the specified activities that cause breathlessness. Ask the patient which level now causes breathlessness and if there is any change from baseline (e.g. can he/she climb less or more flights of stairs, can he/she walk longer or less, can he/she walk steeper or less steep slopes than recorded at the baseline visit?). Select a grade from the index considering that a change of plus/minus one should indicate the minimum that can be recognised by the patient, a plus/minus three means a major change and plus/minus two means any change in between.

Magnitude of Effort:

Review with the patient the effort (exertion, vigour) he/she was able to perform at baseline with the recorded activities until he experienced breathlessness. Ask the patient how much effort no causes breathlessness and whether there is a change from baseline (e.g. does it take more or less time for a certain activity, does he/she need to take less or more pauses and can he perform with more or less effort (exertion, vigour)?). Circle a grade for change in the index or select zero if no change.

(Key Reference: Mahler *et al.*, 1984)

APPENDIX FOUR: A GUIDE TO ADMINISTERING THE SGRQ

What is the St George's Respiratory Questionnaire?

The St George's Respiratory Questionnaire (SGRQ) is designed to measure "health-related quality of life", that is the impact of chest disease on daily life and well-being. Asthma, chronic bronchitis and emphysema can cause major disturbances to daily life, which vary from person to person regardless of lung function.

How should it be administered?

The questionnaires should be completed in a quiet room and the patient should be sat at a desk or table. If the spouse had accompanied the patient try to separate them. It is important that the patient completes the SGRQ themselves, without any advice from their partner.

Explain to the patient why they are completing the questionnaire, and how important it is for us to understand how they feel about their illness and the affect it has on their day-to-day lives. The SGRQ is designed as a supervised self-administered questionnaire. This means that the patient should complete the SGRQ themselves but someone must be available to give advice if it is needed.

Ask the patient to complete the SGRQ as honestly as they can and stress that there are no right or wrong answers, simply the answer that the patient thinks applies to them best. Explain that they must answer every question and that someone will be close at hand to answer any queries.

Do not let the patients take the SGRQ home to be completed. It is important that it is done in the presence of the investigator and that you can be sure it is answered by the patient alone without the help of his/her family.

What should I do about queries?

Answers to some possible queries are given in the guide to completing the SGRQ; beneath each question. Read through this before seeing the patient. It is worth being prepared.

If the patient asks you to help them answer a question, don't give them an answer. The point of quality of life questionnaires is to get an understanding of how the patient views his/her illness. Simply readdress the question back to them.

Questions may be read out to patients who have difficulty in reading, but the responses must be theirs alone.

What should I do when the SGRQ has been completed?

Once the patient has completed the questionnaire read through to check that each and every question has been answered. Don't send the patient away before you have done this. If any questions have been left unanswered, point them out to the patient and ask for answers.

If you see an answer that you disagree with, e.g. the patient ticks that he/she coughs a few days a month, and you know that they cough more often, do not question its accuracy. By asking a patient "are you sure this is right?", you are more or less telling them that you think it is wrong. Since you are the expert, they may change their answer to agree with you even though they still may feel that their first answer was right.

Finally thank the patient for their time and again stress how important and useful this information is.

ST GEORGE'S RESPIRATORY QUESTIONNAIRE
PART 1

Questions about how much chest trouble you have had over the last year. Please tick in one box for each question.

	most days a week	several days a week	a few days a week	only with chest infections	not at all
1) Over the last year I have coughed:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2) Over the last year, I have brought up phlegm (sputum):	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3) Over the last year, I have had shortness of breath:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4) Over the last year, I have had attacks of wheezing:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5) Over the last year, how many severe or very unpleasant attacks of chest trouble have you had?

- more than 3 attacks... ..
- 3 attacks
- 2 attacks... ..
- 1 attack... ..
- no attacks... ..

6) How long did the worst attack of chest trouble last?
(Go to Question 7 if you have had no attacks)

- a week or more... ..
- 3 or more days... ..
- 1 or 2 days... ..
- less than a day... ..

7) Over the last year, in an average week, how many good days (with little chest trouble) have you had?

- no good days... ..
- 1 or 2 good days... ..
- 3 or 4 good days... ..
- nearly every day is good... ..
- every day is good... ..

8) If you have a wheeze, is it worse in the morning?

- no... ..
- yes... ..

PART 2

SECTION 1

How would you describe your chest condition? (Please tick in one box only)

	TRUE	FALSE
the most important problem that I have.....	<input type="checkbox"/>	<input type="checkbox"/>
causes me quite a few problems.....	<input type="checkbox"/>	<input type="checkbox"/>
causes me a few problems.....	<input type="checkbox"/>	<input type="checkbox"/>
causes no problem.....	<input type="checkbox"/>	<input type="checkbox"/>

If you have ever had paid employment, please tick one of these:

	TRUE	FALSE
my chest trouble made me stop work.....	<input type="checkbox"/>	<input type="checkbox"/>
my chest trouble interferes with my work or made me change my work.....	<input type="checkbox"/>	<input type="checkbox"/>
my chest trouble does not affect my work.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 2: Questions about what activities usually make you feel breathless these days. For each item, please tick either true or false as it applies to you.

	TRUE	FALSE
Sitting or lying still.....	<input type="checkbox"/>	<input type="checkbox"/>
Getting washed or dressed.....	<input type="checkbox"/>	<input type="checkbox"/>
Walking around the home.....	<input type="checkbox"/>	<input type="checkbox"/>
Walking outside on the level.....	<input type="checkbox"/>	<input type="checkbox"/>
Walking up a flight of stairs.....	<input type="checkbox"/>	<input type="checkbox"/>
Walking hills.....	<input type="checkbox"/>	<input type="checkbox"/>
Playing sports or games.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 3: Some more questions about your cough and breathlessness these days. For each item, please tick either true or false as it applies to you.

	TRUE	FALSE
My cough or breathing disturbs my sleep.....	<input type="checkbox"/>	<input type="checkbox"/>
My cough makes me tired.....	<input type="checkbox"/>	<input type="checkbox"/>
My cough hurts.....	<input type="checkbox"/>	<input type="checkbox"/>
I get exhausted easily.....	<input type="checkbox"/>	<input type="checkbox"/>
I am breathless when I walk.....	<input type="checkbox"/>	<input type="checkbox"/>
I am breathless when I bend over.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 4: Questions about other effects that your chest trouble may have on you these days. Please tick either true or false as it applies to you.

	TRUE	FALSE
My coughing or breathing is embarrassing in public.....	<input type="checkbox"/>	<input type="checkbox"/>
My chest trouble is a nuisance to my family, friends or neighbours.....	<input type="checkbox"/>	<input type="checkbox"/>
I get afraid or panic when I cannot get my breath.....	<input type="checkbox"/>	<input type="checkbox"/>
I feel that I am not in control of my chest problem.....	<input type="checkbox"/>	<input type="checkbox"/>
I do not expect my chest to get any better.....	<input type="checkbox"/>	<input type="checkbox"/>
I have become frail or an invalid because of my chest.....	<input type="checkbox"/>	<input type="checkbox"/>
Exercise is not safe for me.....	<input type="checkbox"/>	<input type="checkbox"/>
Everything seems too much of an effort.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 5: Questions about your medication. If you are receiving no medication go straight to section 6:

To complete this section please tick either true or false as it applies to you.

	TRUE	FALSE
My medication does not help me very much.....	<input type="checkbox"/>	<input type="checkbox"/>
I get embarrassed using my medication in public.....	<input type="checkbox"/>	<input type="checkbox"/>
I have unpleasant side effects from my medication.....	<input type="checkbox"/>	<input type="checkbox"/>
My medication interferes with my life a lot.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 6: These are questions about how your activities might be affected by your breathing. For each question, please tick true if one or more parts applies to you because of your breathing, otherwise tick false.

	TRUE	FALSE
I take a long time to get washed or dressed.....	<input type="checkbox"/>	<input type="checkbox"/>
I cannot take a bath or shower, or I take a long time.....	<input type="checkbox"/>	<input type="checkbox"/>
I walk slower than other people, or I stop for rests.....	<input type="checkbox"/>	<input type="checkbox"/>
Jobs such as housework take a long time, or I have to stop for rests.....	<input type="checkbox"/>	<input type="checkbox"/>
If I walk up one flight of stairs, I have to go slowly or stop.....	<input type="checkbox"/>	<input type="checkbox"/>
If I hurry or walk fast, I have to stop or slow down.....	<input type="checkbox"/>	<input type="checkbox"/>
My breathing makes it difficult to do things such as walk up hills, carrying things up stairs, light gardening such as weeding, dance, play bowls or play golf.....	<input type="checkbox"/>	<input type="checkbox"/>
My breathing makes it difficult to do things such as carry heavy loads, dig the garden or shovel snow, jog or walk at 5 miles a hour, play tennis or swim.....	<input type="checkbox"/>	<input type="checkbox"/>
My breathing makes it difficult to do things such as very heavy manual work, run, cycle, swim fast or play competitive sports.....	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 7: We would like to know how your chest trouble usually affects your daily life.

Please tick either true or false as it applies to you because of your chest trouble.

(Remember that true only applies to you if you cannot do something because of your breathing)

	TRUE	FALSE
I cannot play sports or games.....	<input type="checkbox"/>	<input type="checkbox"/>
I cannot go out for entertainment or recreation.....	<input type="checkbox"/>	<input type="checkbox"/>
I cannot go out of the house to do the shopping.....	<input type="checkbox"/>	<input type="checkbox"/>
I cannot do housework.....	<input type="checkbox"/>	<input type="checkbox"/>
I cannot move far from my bed or chair.....	<input type="checkbox"/>	<input type="checkbox"/>

Here is a list of other activities that your chest trouble may prevent you doing. (You do not have to tick these, they are just to remind you of ways in which your breathlessness may affect you):

- Going out for walks or walking the dog
- Doing things at home or in the garden
- Sexual intercourse
- Going out to church, or place of entertainment
- Going out in bad weather or into smoky rooms
- Visiting family or friends or playing with children

Please write in any other important activities that your chest trouble may stop you doing.

Now, would you tick in the box (one only) which you think best describes how your chest affects you:

- It does not stop me doing anything I would like to do..... ..
- It stops me doing one or two things I would like to do.....
- It stops me doing most of the things I would like to do....
- It stops me doing everything I would like to do..... .

THANK YOU FOR FILLING IN THIS QUESTIONNAIRE. BEFORE YOU FINISH WOULD YOU PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS

APPENDIX FIVE: MEDICAL RESEARCH COUNCIL INDEX

Grading of Dyspnea

Grade I	Dyspnea on vigorous effort only
Grade II	Troubled by inclines or when hurrying on level ground
Grade III	Short of breath walking with others of similar age and physique, even on level ground, do own shopping
Grade IV	Short of breath with mild activity; cannot walk one block or climb one flight of stairs without stopping for breath.

Holden *et al.*, (1990)

APPENDIX SIX: THE EXERCISE PRESCRIPTION FORM

See the following page.

