A descriptive study to determine the prevalence of obstructive airways disease amongst Load Haul Drivers (LHD) in trackless mines

By

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Declaration

I, Amukelani Portia Manyike hereby declare that this research report, submitted for the degree Master of Public Health at the University of Pretoria, is my own work, except where duly acknowledged, and has not previously been submitted by me for a degree at another university.

Student's Signature: ..... Date: .....

Supervisor's signature: ..... Date: ……..

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Dedications

- I would like to thank my husband Kevin for his constant support, for standing by me even when pressure emerged from all different directions he was there holding my hand; even if it meant he fix supper for me and the kids or drive me to Pretoria to make sure I keep going, Love that is really appreciated.

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Definition of terms

ACGIH: American Conference of Governmental Industrial Hygienists

AME: Advanced medical engineering

AQI: Air Quality Index

CO: Carbon Monoxide

CO_2: Carbon Dioxide

COPD: Chronic Obstructive Pulmonary Disease

COAD Chronic Obstructive Airway Disease

DPM: Diesel Particulate Matter

ECSC: European Community for Steel and Coal

FVC: Forced Vital Capacity

FEV1: Forced Expiratory Volume 1 minute

GOLD: Global Initiative for Chronic Obstructive Lung Disease

IARC: International Agency for Research on Cancer

IgE: Immunoglobulin-E

LHD: Load Haul Driver

MHSA: Mine Health and Safety Act

MSHA: Mine Safety and Health Administration

$m^3/s/kW$: Cubic meters per second per kilowatt

m^3/s: Cubic meters per second

NIOSH: National Institute for Occupational Safety and Health

NO: Nitrogen Monoxide

NO_2: Nitrogen Dioxide

NO_x: Nitrogen Oxides

N_2:	Nitrogen
OAD	Obstructive Airway Disease
OLDs:	Occupational Lung Diseases
O_2:	Oxygen
OC:	Organic carbon
OEL:	Occupational Exposure Limit
OEM:	Original Equipment Manufacturer
PAH:	Polycyclic Aromatic Hydrocarbons
PPE:	Personal Protective Equipment
µm:	Micrometer
µg/m³:	Micrograms per cubic meter of air
SANS:	South African National Standards
SO_2:	Sulphur Dioxide
SO_3:	Sulphate
TC:	Total carbon
TWA:	Time Weighted Average
%:	Percent
°C:	Degree Celsius

ABSTRACT

Background: During day to day mining activities, miners are exposed to different airborne pollutants, which may result in occupational lung diseases (OLDs). In South Africa mining is a primary industrial activity that contributes significantly to the gross domestic product (GDP). Mine related lung diseases depend on the type of commodity that is mined, aerodynamic size of airborne pollutants, exposure time, environmental conditions and the employee's lifestyle.

Aim and Objectives: To determine the prevalence of obstructive airway disease amongst load haul drivers (LHD) occupationally exposed to mineral dusts and diesel particulate matter (DPM) in trackless mines. The study was also aimed at determining the relationship of selected epidemiological determinants on the status of obstructive airway disease in LHD and to determine whether a difference existed between employees that worked only day or night shift.

Methodology: The study area was a platinum mine in Mpumalanga. The study population comprised of underground LHD drivers who were frequently exposed to mineral dust and DPM during loading and off-loading of raw minerals. The study population was divided into two groups: day shift and night shift, a questionnaire was used to obtain information on demographics; self-reported social and health history, including respiratory symptoms. Spirometry was performed to determine the Forced Vital Lung Capacity (FVC) and Forced Expiratory Volume 1 sec (FEV_1). Employees who presented an FEV1/FVC of <70% underwent a second spirometry after using a bronchodilator (Combivent, 0.5mg ipratropium bromide anhydrous, 2.5mg salbutamol base, & 0.52mg ipratroniumbromide).This was done to rule out reversible obstructive lung cases.

Results: Employees on night shift had a significantly higher prevalence of obstructive airway disease patterns (32.6%) compared to the day shift prevalence (12.5%). There was a significantly higher ($p = 0.009$) prevalence of acute coughing in night shift LHD (41.3%) compared to day shift LHD drivers (15.0%)). Over 3 months, night shift workers (73.68%) also presented with

significantly more (p = 0.036) symptoms of chronic coughing than day shift workers (0.00%) night shift workers (47.83%) presented sputum production while day shift workers presented only 14.29%. Furthermore, night shift LHD showed a significance change (p = 0.729) in measured lung function of FEV1/FVC, in comparison with day shift LHD. Multivariate regression analysis also showed that night shift LHD had a 3 times higher odds of developing obstructive airway disease than day shift workers (OR 3.30, 95% Cl 1.08, 10.04, p = 0.036).

Conclusion: The night shift LHD drivers presented a marked reduction in lung function as well as acute and chronic respiratory symptoms. It is therefore concluded that night shift LHD are at higher risk of developing obstructive airway disease when exposed to diesel particulate matter as compared to day shift workers.

Keywords: Obstructive Airway Disease, Diesel Particulate Matter, Forced Expiratory Volume, Forced Vital Capacity, Acute and Chronic Cough.

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1. INTRODUCTION

Occupational injuries and ill-health have huge social and economic implications for individuals, their families and their communities. [1] This is because employees become medically incapacitated and can no longer provide for their families because of ill health and the costs it involves. Exposure to respirable mineral dust has been linked to respiratory disease in the mining industry. [2,3,4] In addition, exposure to diesel particulate matter (DPM) due to trackless diesel powered machines, may add to the toxicological burden on the lungs of the LHD operators. It may therefore be necessary to include DPM as a variable responsible for respiratory diseases currently reported in the mining industry. Between1973 to 1993 (20 years) the Medical Bureau for Occupational Disease certified 128 575 cases of occupational lung disease. [1] Hermanus [1] indicated that cases may be under estimated, since the majority of black workers exposed to respirable dust, were not previously entitled to the benefit of examination.

1.1. CHRONIC OBSTRUCTION PULMONARY DISEASE

Chronic obstructive pulmonary disease (COPD) is characterized by the gradual progression of irreversible airflow obstruction and increased inflammation in the airways and lung parenchyma, that is generally distinguishable from the inflammation caused by asthma.[5] Patients with COPD present with a variety of clinical findings, including elements of chronic bronchitis and emphysema. [6] The cells that are associated with COPD are alveolar macrophages, neutrophils, and cytotoxic $CD8^+$ effector T lymphocytes. These cells progressively infiltrate the parenchyma. This causes mucus production, destruction or pathology of the extracellular matrix in the alveolar walls and lung tissues, leading to emphysema. [7] Diagnosis of COPD can be done using airflow limitation and is best measured by spirometry, before and after bronchodilation (to exclude asthma). This is the most widely available reproducible test of lung function. [5]

1.2. RISK FACTORS

The primary cause of COPD is often considered to be smoking. [8] Studies have indicated that about 94% cases in the United States occurred amongst current or former smokers. [5] Louis [5] explained that the link between tobacco smoke exposure and COPD comes from population-based studies. These have consistently shown that smoking is associated with diminished lung function, more frequent respiratory symptoms and increased COPD-related deaths. Lee and Fry [9] also indicated that in people who continue smoking there is an average rate of decline in FEV1 that is substantially greater than that of people who have never smoked. On the other hand, studies have indicated that exposure to dusts and other irritants may also cause chronic obstructive lung disease, which has subsequently been called COPD.

Airborne respirable dust is produced during mining, the cutting, breaking, crushing, drilling, grinding or loading of ore and surrounding rock. [4] Drilling or cutting of rock is followed by blasting at the end of the working shift. During blasting fine dust is generated and is carried away by the ventilating air stream, throughout the mine and exhausted by the main surface fans. However a large quantity of dust is trapped with the rock that is broken during blasting. Some of the coarse particles that become airborne during blasting settle out on the footwall. If precautions such as watering down before loading are not taken, these settled particles can become airborne and can be inhaled by the LHD after blasting.[4] Miners may develop various occupationally-related respiratory diseases including COPD, depending on the type of materials and level of exposure. In particular, COPD is known to be a feature of silicosis cases.[2,3,4]

1.3. DIESEL PARTICULATE MATTER

The LHD are not only exposed to air borne dust during loading, they are also extensively exposed to diesel particulate matter (DPM) due to the utilisation of diesel powered machines in the underground mining environment. Diesel particulate matter is defined as a sub-micron (< 1.0 micron) physical aerosol component of diesel exhaust, which is made up of solid carbon particles. It is composed of vapours, gases and fine particles.[10] It is suspected that DPM is a risk factor towards

occupational asthma, because it is an irritant which can induce inflammation. However, a study by Adewole et al. has indicated that exposure to DPMs at 200 µg/m^3 can cause sputum neutrophilia, without changes in forced expiratory volume in 1 second (FEV_1).[11] Furthermore, there has not been an identified link between DPM exposure and chronic obstructive airway disease (COAD). On the other hand, smoking may act as a confounder because a study of the literature has indicated that smoking is the main cause of COPD.

1.4. COMPOSITION OF DIESEL PARTICULATE MATTER

Diesel exhaust can be composed of two phases, gaseous or particulate. Both of these can increase the risk of COPD.[12] The gaseous phase consists largely of the same gases found in air, nitrogen, oxygen, carbon dioxide and water vapour,[13,14] It also contains hazardous air pollutants, such as acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde and polycyclic aromatic hydrocarbons. Diesel particles are classified according to size or composition. Those of greatest health concern fall into the categories of, fine and ultrafine particles. Fine and ultrafine particles may be composed of elemental carbon, with adsorbed compounds such as organic compounds, sulfate, nitrate, metals and other trace elements.[14] The solid particulate fraction comprises of very small particles (typically 15-30 nm diameter) that rapidly agglomerate to form “chains” or clumps , which are typically <1µm aerodynamic size. [13, 14]

1.5. SCHEMATIC DIAGRAM OF A PARTICULATE MATTER [Analytical]

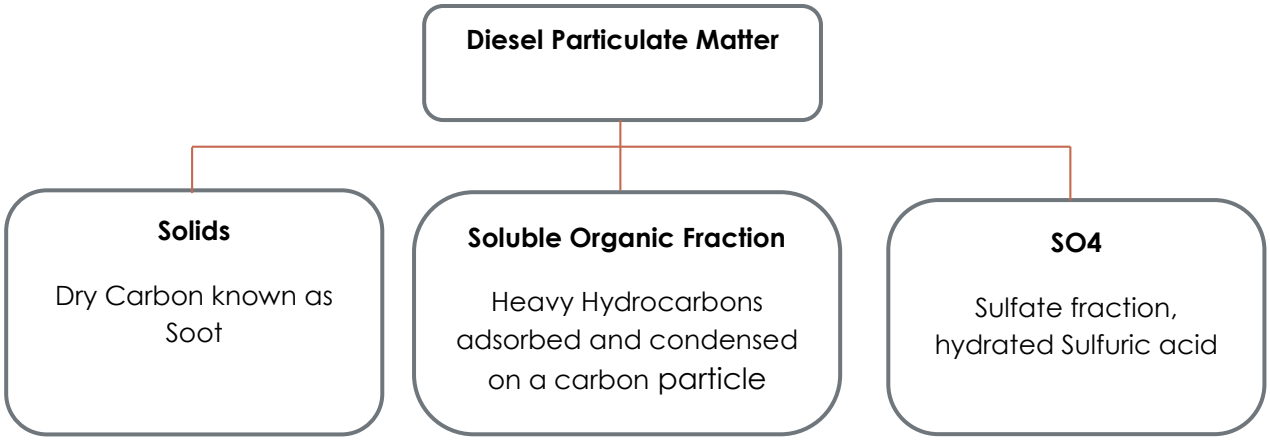

Figure 1: Classification of particulate matter in diesel fumes. [16]

Fig 2 below show the structure and composition of diesel particulate matter

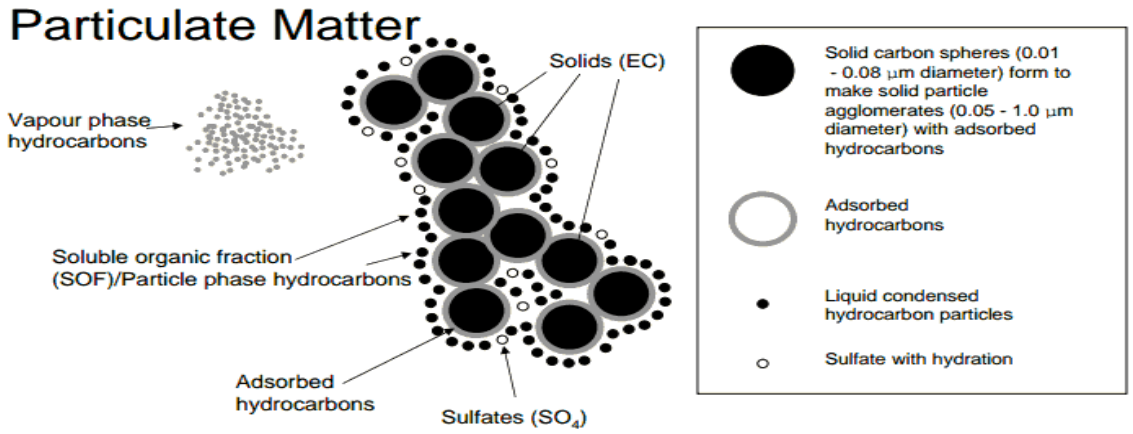

Figure 2: Structure and composition of diesel particular matter. [16]

Diesel particulate matter has the potential to induce adverse health effects and is also regarded as a danger to the environment by the United States Environmental Protection Agency (USEPA), who claim that it is among the top twenty air pollutants.[16] In terms of health outcome, the very small particle size of DPM is important, as this means it can reach the deepest parts of the lungs. Particulate overload, rather than chemical composition, is thought to be the major mechanism leading to its toxic effect.[13]

1.6. RESPIRABLE DUST

Respirable dust is defined as particles which are less than 10 micrometers in diameter and cannot be seen with the naked eye. Information available on exposure to airborne health hazards suggest that, depending on the commodity under consideration, between 9% and 50% of exposed workers (about half of the workforce), are overexposed to airborne pollutants.[2] Airborne respirable dust that is inhaled by miners can be deposited in the lungs and cause damage to the lung tissue.

A number of studies have been conducted on COPD and silica dust exposure in the mining sector and platinum refinery plants. Previous epidemiological studies have

shown that silica dust exposure can lead to airflow obstruction in the absence of radiological signs of silicosis.[17] Literature on the direct health effects associated with raw platinum ore, are however limited. The silica quartz content of platinum ore is often low. Exposure measured in South African platinum mines have indicated that operators are exposed to low levels of respirable crystalline silica.[4,8] However, the association between cumulative silica dust exposure and airflow obstruction can be independent of silicosis.[6] In workers exposed to silica dust, lung fibrosis and pulmonary tuberculosis can contribute to airflow obstruction.[3] The focus area has been based on the effects of silica dust, consequently several studies have been conducted in gold mines where the concentration of silica was known to be high.

1.7. HEALTH EFFECTS

In terms of health outcomes, the very small particle size of DPM is important, as it can reach the deep parts of the lungs. Particulate overload, rather than chemical composition, is thought to be the major mechanism leading to toxic effects.[14] Particle size is directly related to potential for causing health problems. Particles >2.5 micrometers in diameter can be inhaled deeper into the lungs. Scientific studies have linked exposure to high concentrations of some types of particulate matter with a variety of problems, including.[18]

- irregular heartbeat;
- aggravated asthma;
- decreased lung function;
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing;
- nonfatal heart attacks; and
- premature death in people with heart or lung disease.

1.8. ACUTE AND CHRONIC HEALTH EFFECTS

Acute exposure to diesel exhaust may cause irritation to the eyes; nose; throat and lungs, as well as neurological effects such as light-headedness. Acute exposure may also elicit coughing, nausea or exacerbate asthma. Chronic effects may range from chronic bronchitis, lung tissue damage and even cancer. Chronic exposure in experimental animal inhalation studies, have shown a range of dose dependent lung inflammation and cellular changes in the lung, as well as the immunological effects of diesel exhaust. There is considerable evidence that diesel exhaust is a possible carcinogen. Human epidemiological studies have demonstrated an association between diesel exhaust exposure and increased lung cancer rates in occupational settings.[19]

1.9. GOLD SCORES

Spirometry is used for diagnosing and monitoring the progression of COPD.[5] The American Thoracic Society has developed GOLD (Global Initiative for Obstructive Lung Disease) scores for COPD, in order to classify the severity of non-reversible airflow obstruction. When measuring spirometry, sex, age, height, and population group is taken into consideration in order to compare the FEV_1 and FVC with the reference or predicted values of a healthy person of the same demographic group. The symptoms related to COPD are recorded in order to classify the disease status. These include coughing, increased sputum production and dyspnea.[12,13] A list of symptoms is attached as addendum A. This was used to collect information from interviewed subjects, before they proceeded to spirometry testing. In addition, Table 1 below shows clinical features used to differentiate between COPD and asthma [12] in the subjects tested. Table 2 shows the spirometry GOLD classification.[7]

Table 1: Clinical features useful in differentiating COPD from asthma. [12]

Clinical feature	COPD	Asthma
Age	Older than 35 years	Any age
Cough	Persistent, productive	Intermittent, usually non-productive
Smoking	Typical	Variable
Dyspnea	Progressive, persistent	Variable
Nocturnal symptoms	Breathlessness, late in disease	Coughing, wheezing;
Family history	Less common	More common
Atopy	Less common	More common
Diurnal variation in symptoms	Less common	More common

Table 2: Spirometric GOLD classification of COPD severity based on post-bronchodilator FEV1 [7].

Stage	Description	Predicted values (based on post-bronchodilator FEV1)
0	At risk	Risk factors and chronic symptoms but normal spirometry
I	Mild	FEV1/FVC ratio less than 70 percent FEV1 at least 80 percent of predicted value May have symptoms
II	Moderate	FEV1/FVC ratio less than 70 percent FEV1 50 percent to less than 80 percent of predicted value May have chronic symptoms
III	Severe	FEV1/FVC ratio less than 70 percent FEV1 30 percent to less than 50 percent of predicted value May have chronic symptoms
IV	Very severe	FEV1/FVC ratio less than 70 percent FEV1 less than 30 percent of predicted value or FEV1 less than 50 percent of predicted value plus severe chronic symptoms

1.10. DIAGNOSTIC TOOLS

1.10.1 GOLD STAGING

Predicted values for FVC and FEV1 are calculated from equations based on age, height, gender and ethnic group, because these are the most important determinants of lung and airway size in healthy individuals.[13,14,20] These values were derived from scientific studies of Caucasians, such as the European Community for Steel and Coal (ECSC). Louw [20] studied the South African male population, which indicated differences in lung size between African black and white males. Black males had

smaller lungs than white males of the same height and age, due to the limb length to chest ratio. As a result; the predicted values for black males must be adjusted with a specific factor, in order to obtain normal spirometry results. The South African Thoracic Society standards of the spirometry committee, use a factor of 0.9, which is substituted in equations to get corrected reference values.[20] The COPD staging is categorized from stage 0 (for at risk individuals) through to stage IV (individuals at a severe stage), However for the at risk population, GOLD [15] indicates that there are no conclusive studies that govern stage 1, therefore it is normally omitted when listing the GOLD staging.

1.10.2 SPIROMETRY

An AME Spirometer was used to measure air flow in the lungs. Lee and Fry [4] described FEV1 as a marker of chronic obstructive lung disease. In GOLD COPD, classifications are used to describe severity of the obstruction or airflow limitation. The worse a person's airflow limitation is, the lower their FEV1 [5]. As COPD progresses, FEV1 tends to decline.

AIM AND OBJECTIVE

The aim of this study was to determine the prevalence of Obstructive Airway Disease (OAD) among LHD drivers occupationally exposed to mineral dusts and diesel particulate matter in trackless mines and the objective were to determine how selected epidemiological determinants affected the status of OAD in LHD working on day or night shifts.

2. RESEARCH QUESTION

Is there a difference in the prevalence of obstructive airway disease when spirometry results of night shift and day shift load haul dump drivers in trackless mining are compared?

3. METHODOLOGY

3.1. Study Design

A descriptive cross-sectional design approach was used for the study. Study participants were LHD working underground in a Platinum trackless mine in Mpumalanga Province, South Africa. The job occupation required loading and tipping of mined ore to different tipping points after blasting. All participants were exposed to diesel fumes, dust and traces of blasting fumes (night shift only).

The participants were divided into two groups, night shift and day shift. Only participants contracted to work permanently on day- and night shift schedules were selected to take part in the study. A questionnaire was administered at their respective working areas, consent to participate was given by all employees before completing the questionnaire. The questionnaire was divided into four categories; demographic and social information, work and exposure history and respiratory symptoms. The second part of the data collection included the measurement of lung function (spirometry) which took place at the mine clinic. Each participant was assigned a unique study number; the participant's company number was replaced by unique study number after all other relevant data was obtained. The unique number was used in the final data set to ensure confidentiality.

3.2. Study Participants (inclusion and exclusion)

Due to the cross-sectional study design, the initial protocol aimed at comparing LHD drivers from platinum mine and chrome mine (n= 400). However, an unforeseen illegal industrial action took place at the Chrome Mine division. All participants of the Chrome Mine division were excluded from the study since they were not available to enrol in the study. Another outcome of the illegal industrial action was that most of the employed LHD drivers were dismissed from their jobs and replaced with new employee crews who had not been exposed to hazards present in the workplaces under investigation.

The inclusion criteria for the study was based on the ground that the participants must have been exposed to hazards of interest and have been an LHD driver for a minimum of 3 years. Female participants were also excluded from the study due to the small representative number. A total number of 90 LHD participated in the study. Of the 90 participants three were female. Of the remainder, 40 employees were working on a continuous day shift and 47 were working on a continuous night shift schedule.

The purpose of the study was explained to the participants before they could volunteer to be part of the study. Employees who agreed to participate were blocked from entering the mine until they had visited the clinic for lung function tests as described below.

3.3. Measurements: Methodology and Study Questionnaire

Subjects were required to complete an administered questionnaire to obtain information on their demographics; self-reported social and health history, including respiratory symptoms (Addendum A1). Spirometry was conducted to determine the Forced Vital Lung Capacity (FVC) and the Forced Expiratory Volume 1 second (FEV1): A broncho dilator was administered to employees who had an FEV1/FVC of <70% prior to a second spirometry measurement. The bronchodilator used was Combivent (0.5mg ipratropium bromide anhydrous, 2.5mg salbutamol base, & 0.52mg ipratroniumbromide). This was done to rule out reversible obstructed lung cases.

3.4. Measuring Procedure

A step by step process was followed when taking measurements:

- Employees were paraded at the clocking access point to the occupational hygiene office
- They were then referred to the clinic station for completing the questionnaire and spirometer measurements
- On arrival at the clinic, the employee completed a demographic, social and symptoms information

- A list of demographic, social and symptoms information is attached as addendum A. This was used to collect information from interviewed subjects, before they proceeded to spirometry testing.
- Each participant underwent a spirometry test to determine the FVC and FEV1.
- The body weights of participants were measured with subjects wearing light clothing and barefoot on a weighing scale. The standing height was measured without shoes with the participant's back to a vertical backboard.
- For subjects with FEV1 of less than 70%, a second spirometry was performed after a week with the administration of a bronchodilator.
- A fixed format was used to log the interview questions as well as spirometry results.
- Three copies of the collected data were generated; and distributed to the participant, participant's file and a research file respectively.

The following variables were controlled to ensure the quality of the results:

- Participants were coached on how to perform a spirometer, prior the tests.
- The participants were asked to blow the spirometer three times, to produce reproducible results. The results which were found to be not reproducible were discarded and the participant was only allowed to continue blowing the spirometry with a limit of 8 attempts, more than 8 attempts was not accepted.[20,21]
- The highest measurement of the set only was used.
- Factors that could influence the spirometry tests such as coughing, hesitation, obstruction of mouth piece and leaking around the mouth piece, were monitored by the technician and the researcher during measurement to ensure quality results.

3.5. Ethical Issues

The study was approved by the Ethics Committee of the Faculty of Health Sciences, University of Pretoria, Ethics protocol number S178/2012.

The mine gave permission in writing, to conduct the research at their workplace; a letter outlined all the aspects that were to be addressed on the study (Addendum A2)

- A signed document was submitted together with the final protocol.
- A consent form was signed by all participants who volunteered for the study; consent form was explained to each participant prior to participation.
- The participant did not receive any payment or other compensation for participation in the study; it was voluntary participation.
- No information that could identify any participant individually was released to anyone outside the study, including employers. No information that will be used for publication from the study will identify any participant individually.
- Confidentiality was maintained by means of a unique number.
- Participants were informed that they could withdraw at any time, without consequences of any kind. They could also refuse to answer any questions they did not want to answer. They were also informed that there would not be any penalty if they withdrew from the study and that they would not lose any benefits or current jobs to which they were otherwise entitled.

3.6. Statistical analysis

Collected data was entered twice into an Excel spreadsheet, to ensure correct data entry. The data cleaning process involved two people, the researcher and the nurse; questionnaire data was entered manually for the second time, to ensure that information on the hardcopy was captured correctly. Data was then exported to Stata 12 for analysis, [StataCorp.2011.Stata Statistical Software: Release 12. College Station, TX: StataCorp LP].

Advanced Medical Engineering (AME) Spirometry readings were used to compare the risk of obstructed lung patterns between day shift and night shift participants. The resulting data was in the form of frequencies in each category.

Descriptive and demographic data were presented as histograms, box plots and in tables as appropriate. For descriptive statistics, numerical data were analysed using frequency distributions. Visual appraisal of histograms or the Shapiro-Wilk test was

used for comparison of frequency distributions. If frequencies were normally distributed they were summarised using arithmetic means and standard deviations. If they were not convincingly normally distributed (i.e. skewed) they were summarised using the medians and inter-quartile ranges. Binary variables were summarised as proportions.

For logistic regression analysis there were three main outcomes of interest, namely: obstructive airways (any cause); obstructive airways (non-reversible following broncho-dilation); and obstructive airways (reversed dilation). In this study the broncho-dilation was only performed for 20 of the participants. Consequently, the pre-bronchodilation results were used to generate the effect measure of interest: the ratio of FEV1:FVC. Those with a ratio of less than 0.70 were considered to be impaired and were coded as one (1). Those with ratios ≥ 0.70 were considered to have “normal” airways flow and were coded as zero for the purposes of logistic regression.

The main exposure variable of interest was whether the participant worked on the night shift (coded as 1) or the day shift (coded as 0). Additional variables were recorded for each participant based on evidence that they might have had an effect on airways obstruction and hence might confound the relationship between type of shift and airways obstruction. These were age, smoking, years spent in the current job and previous history of pulmonary tuberculosis. The relationship between type of shift and each of the three outcome measures was modelled using binary logistic regression analysis.

If an explanatory variable was modelled as a continuous variable then a Box-Tidwell test was performed to assess whether the continuous variable was linear in its relationship with the logit of the model. If it was not linear it was recoded as a binary variable. A Box-Tidwell variable p-value of 0.05 or less was considered significant and resulted in recoding as a categorical variable.[16,21]

Post regression testing included estimation of the area under the Receiver Operating Characteristic (ROC) curve and the performance of the Hosmer-Lemeshow goodness of fit test. This test was used in preference to the Pearson’s goodness-of-fit test because the number of covariate groups was almost equal to the sample size in each

model (due to the inclusion of at least one continuous variable in each model). The Hosmer-Lemeshow test was carried out, as recommended by Hosmer and Lemeshow, using three different numbers of groups: 8, 10 and 12. This was done as a kind of sensitivity analysis since the test is considered to be not generally as reliable as the Pearson's test.[16,21]

4. RESULTS

4.1. Study population

Out of 110 LHD drivers at the selected Platinum mine (Table 3), 90 participated in the study (Table 3). Eighty seven (n=87) participants were males and three were female. Forty (n=40) employees worked on a fixed day shift and the remainder, n=50 worked on a fixed night shift according to organisational structure that does not permit any rotation between day and night shift crews. In summary, 80% of day shift participant's workforce participated in the study, whilst 83% night shift workforce participated in the study.

Table 3: Summary data of participants.*

Variable	Day Shift	Night Shift	Total
Number of female LHD drivers	5	8	13
Number of males LDH drivers	45	52	97
Total Number of LHD drivers	50	60	110
Number participated in the study females	0	3	3
Number participated in the study males	40	47	87
Total Number participated in the study	40	50	90

***Footnote:**
40/50(80%) of day shift employees participated in the study
80% of the day shift responses were male employees
47/60(83%) of night shift employees participated in the study
78.3% of the night shift responses were male employees and 5% female employees
Female employees were excluded from statistical analysis due to small number (3 participants)

4.1.1. Reasons for non-response

Table 4: Reasons why workers chose not to be respondents.

Variable	Group			
	Day Shift		Night Shift	
	Female	Male	Female	Male
Employees on leave	2	1	2	0
Employees on training	3	1	3	0
Opted not to participate	0	3	0	5

Some employees opted not to participate in the study due to several reasons. Firstly there was no reimbursement to participate in the study. They also feared that the information they gave might be forwarded to management and could result in job loss. Further, they wanted a written guarantee stating they would be compensated by the compensation fund after the study. Female employees who did not participate were either on leave or on a training course, none of the female workers on duty opted not to participate in the study.

4.1.2. Workplace Activities

Differences between day and night shift are shown in Table 5.

Table 5: Workplace observations recorded during the study.*

Day Shift	Night Shift
Ventilation design quantity per one LHD loading = 9m^3/s using 0.12 m^3/s per kW (m^3/s/kW)	Ventilation design quantity per one LHD loading = 9m^3/s using 0.12 m^3/s per kW (m^3/s/kW)
Mainly drilling & blasting	Mainly loading and hauling
1-2 LHDs loading in a section	4-6 LHDs loading in a section
Proper watering down before the start of shift when preparing to drill	Airborne dust suspension is generated in the atmosphere after blasting. No watering down before loading starts
No traces of blasting gases and vapours	Possible traces of blasting gases and vapours
Effective supervision. Appointed shift supervisors for each section during the morning shift. Appointed mine captains for day shift	Poor supervision. Shift supervisor appointed for more than one section at night where it is difficult to monitor all working places. No Mine captains during night shift
Proper early entry workplace examination. All hazards are identified and fixed before work can take place. The declaration book is countersigned by the section supervisor. Planned task observations are conducted before work takes place	Poor entry workplace examination. Due to shortage of supervision declaration book is not completed, and planned task observation are not conducted
One pair of dust mask adequate for the shift	One pair of dust mask become clogged with fumes during the shift – One pair not enough

***Note:** The LHD does not have an enclosed cabin to prevent the employee from being exposed. The ventilation design parameters are the same during the different shifts, which means that the available quantity of air remains the same regardless of the risk of exposure during loading period.

4.1.3. Demographic Characteristics

Table 6 shows the demographic information, social information and spirometry information results for the study population which consisted of 90 LHD drivers. The mean, median & interquartile range (IQR) of age, body mass, height, cigarettes smoked per day, years of smoking, years working in current job and spirometry variables are presented.

The study comprised of 95% male participants whilst only 5% of the participants were female. Females were excluded from analysis due to the small sample size. The day shift and night shift groups did not differ significantly in respect of age, weight, height and social factors such as smoking. In addition it can be concluded that these variables did not have an effect on the lung function results. There was no

significant difference between baseline FEV1/FVC for the day shift and night shift participants; as a result statistical inference for the change in baseline readings was not conducted. However there was a distinctive difference on the current FEV1/FVC (lung function measured conducted during the research).

Table 6: Demographic characteristics, smoking history and lung functions of the day and night shifts participants respectively.[#]

	Day shift (n = 40)	Night shift (n = 47)
Age (years) Median (IQR)	35.0 (31.6-41.4)	36.4 (31.6-44.8)
Body mass (Kg) Median (IQR)	67.8 (61.2-84.7)	70.4 (61.9-82.3)
Height (cm) Mean (SD)	171.78 (6.12)	171.85 (6.24)
Cigarettes smoked per day Median (IQR)	4.0 (3.5-6.0)*	3.5 (2.8-5.8)**
Years smoking Mean (SD)	14.38 (10.32)*	5.0 (3.0-9.3)**
Years smoking Mean ; (SD) Median (IQR)		5.0 (3.0-9.3)**
Years working current job Median ; (IQR)	5.0 (3.0-9.5)	5.0 (3.0-7.0)
Baseline FVC (L) Mean (SD)	4.14 (0.58)	4.07 (0.59)
Baseline FEV1 (L) Mean (SD)	3.39 (0.59)	3.35 (0.48)
Baseline FEV1:FVC Mean (SD)	0.82 (0.10)	
Baseline FEV1:FVC Median (IQR)		0.83 (0.8-0.9)
Current FVC (L) Mean (SD)	4.08 (0.75)	3.79 (0.62)
Current FEV1 (L) Mean (SD)	3.29 (0.65)	2.89 (0.62)
Current FEV:FVC Mean (SD)	0.81 (0.08)	
Current FEV:FVC Median (IQR)		0.77 (0.7-0.8)

***n = 13**
****n = 18**

[#]Note: Degree of accuracy
The following variables were rounded off:
Total years spent as LHD driver was rounded to a whole number, i.e: 1.2 years of exposure was rounded off to 1 year and 1.5 years of exposure was rounded off to 2 years. The information was captured as either median (IQ) or mean(SD) depending on the data spread with the first referring to non-symmetrical data and the second referring to symmetrical data spread.

The histogram depicting age distribution for the participants is shown in Figure 3.

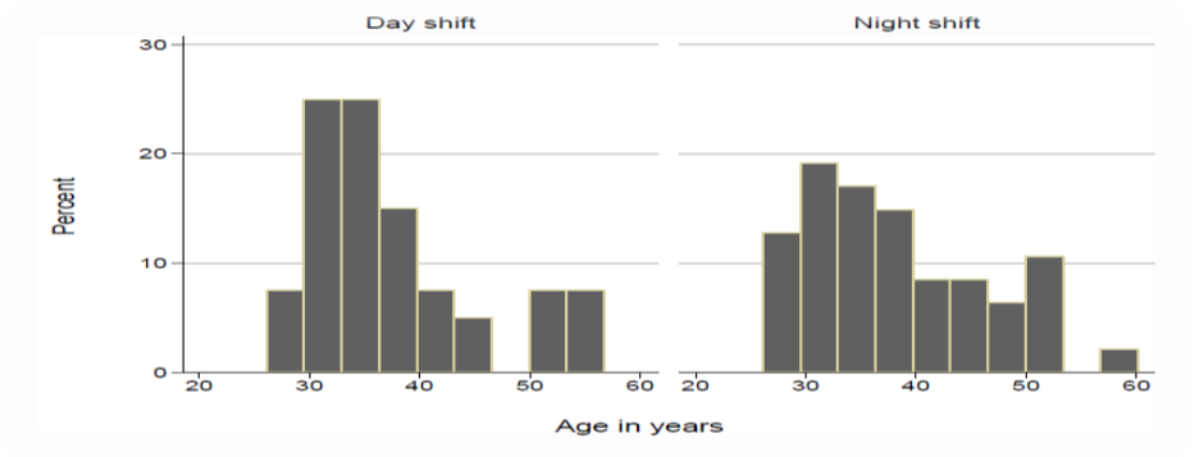

Figure 3: Shows age distribution in the form of a histogram, depicting age distribution for the day shift and night shift participants

A histogram depicting body mass distribution for the day shift and night shift participants is shown in Figure 4. Body mass (kg) was not normally distributed in either night shift or day shift workers.

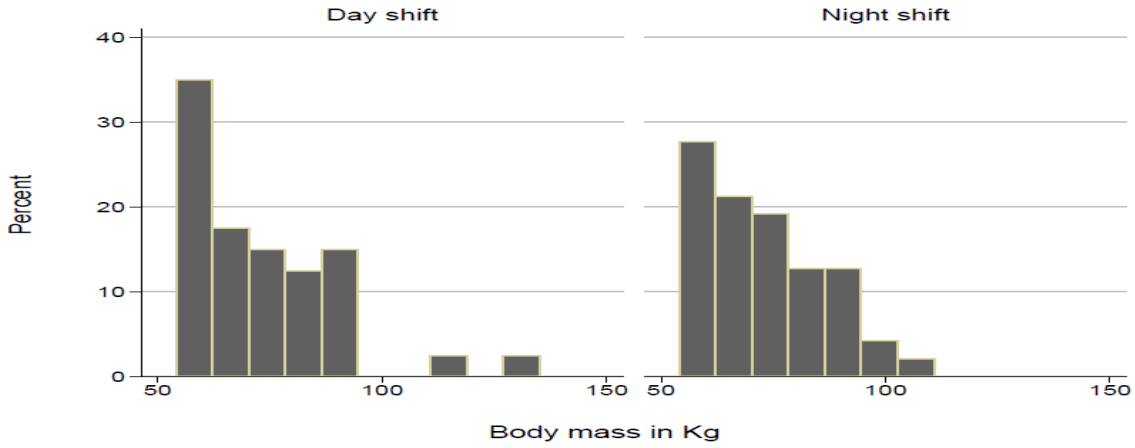

Figure 4: **The histogram depicting body mass (kg) of the participants.**

The following histogram depicts height distribution for the day shift and night shift participants (Figure 5).

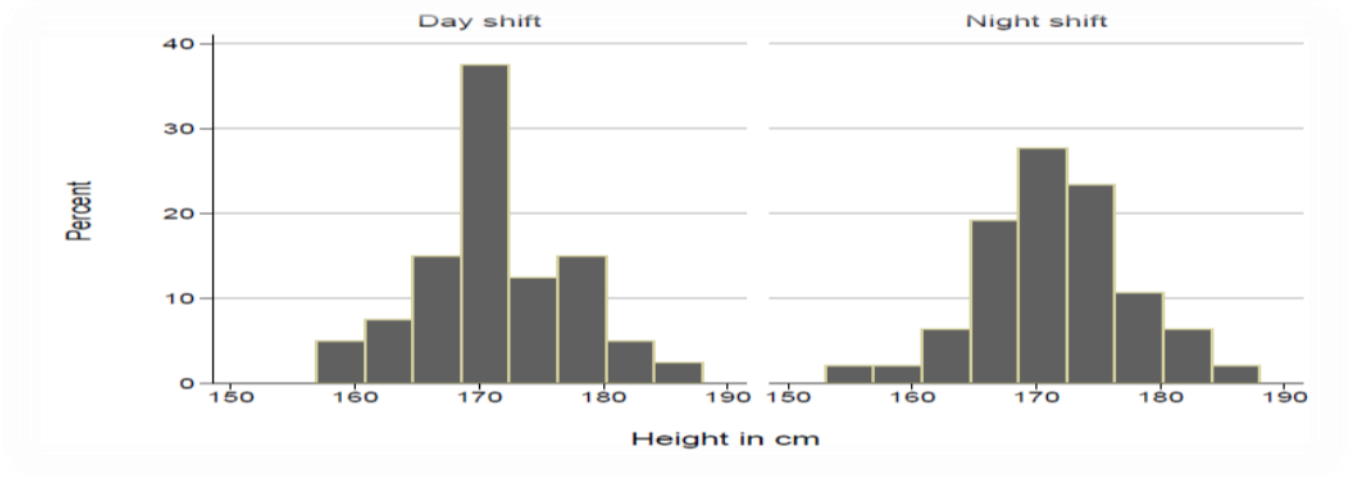

Figure 5: Histogram depicting a normally distributed height (cm) for night shift and day shift participants respectively.

The histogram depicting years in current position distribution for the day shift and night shift participants is shown in Figure 6.

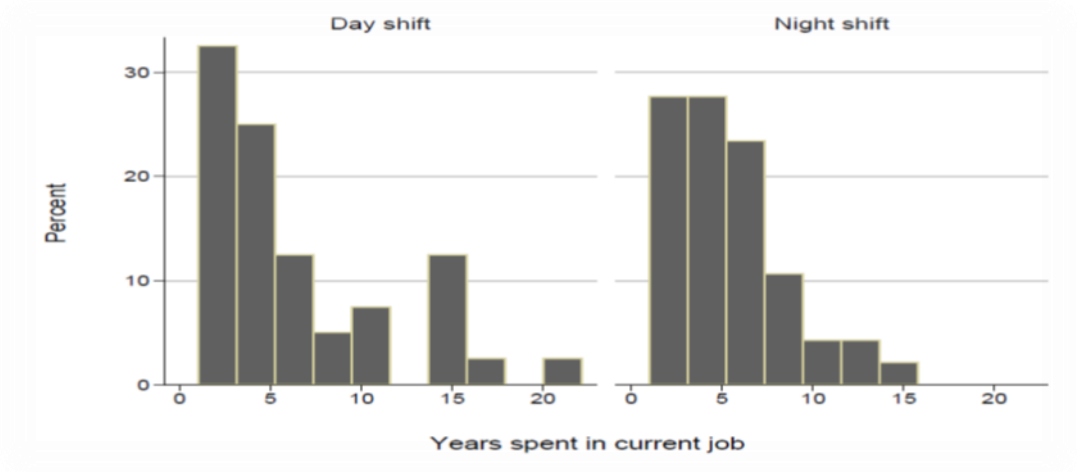

Figure 6: Histogram depicting the years spent in current job.

It can be seen that the data in Figure 6 is not normally distributed.

4.2. Data Analysis – Graphical and Tabular Presentations

The histogram depicting post-broncho-dilation by shift is shown in Figure 7, below.

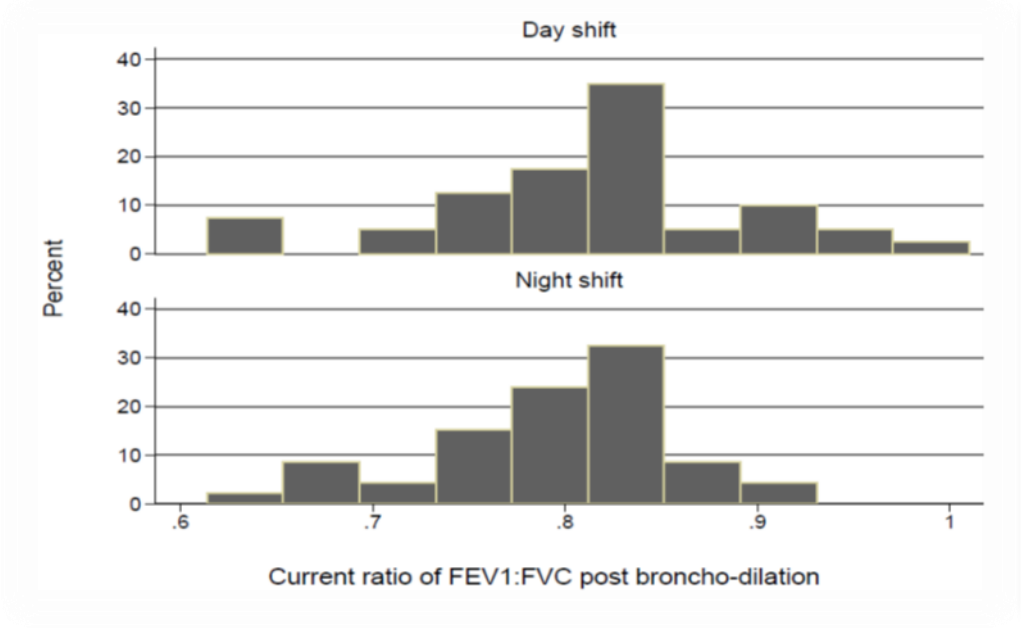

Figure 7: Histogram depicting a normally distributed current ratio of FEV1/FVC for a day shift and the skewed pattern of current ratio of FEV1/FVC for night shift participants.

Figure 8 compares baseline spirometry results measured from AME Spirometry, according to shift.

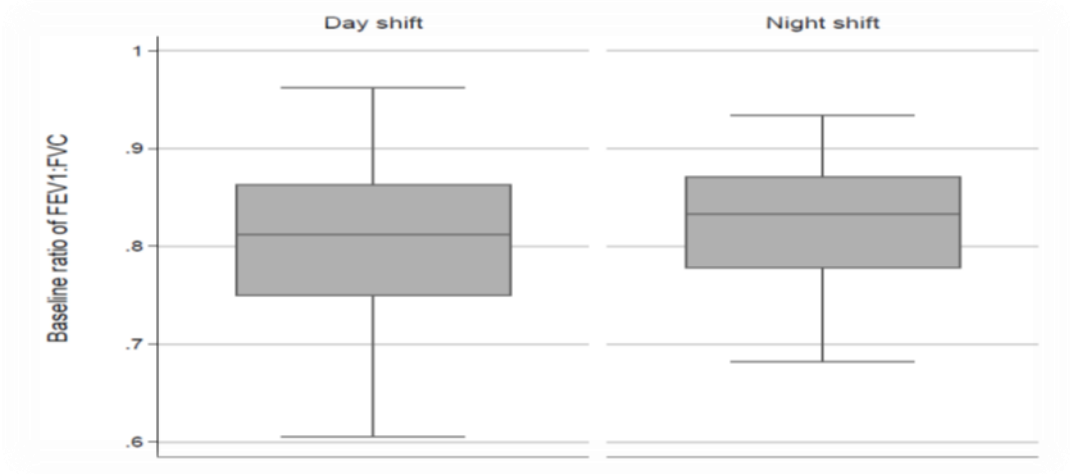

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Figure 8: Box plot depicting baseline ratio of FEV1/FVC.

Figure 9 shows a Box Plot representing the spirometry results measured from AME Spirometry, this is labelled as current lung function which was measured during the time of study .

Figure 9: Box plot depicticting current ratio of FEV1/FVC.

Figure 10, below, shows a Box Plot representing the spirometry results measured from AME Spirometry, this is labelled as current lung function with post bronchodilation. which was measured during the time of study, as LHD drivers who presented an FEV1/FVC of ≤ 70 were subjected to a second spirometry with a bronchodilator.

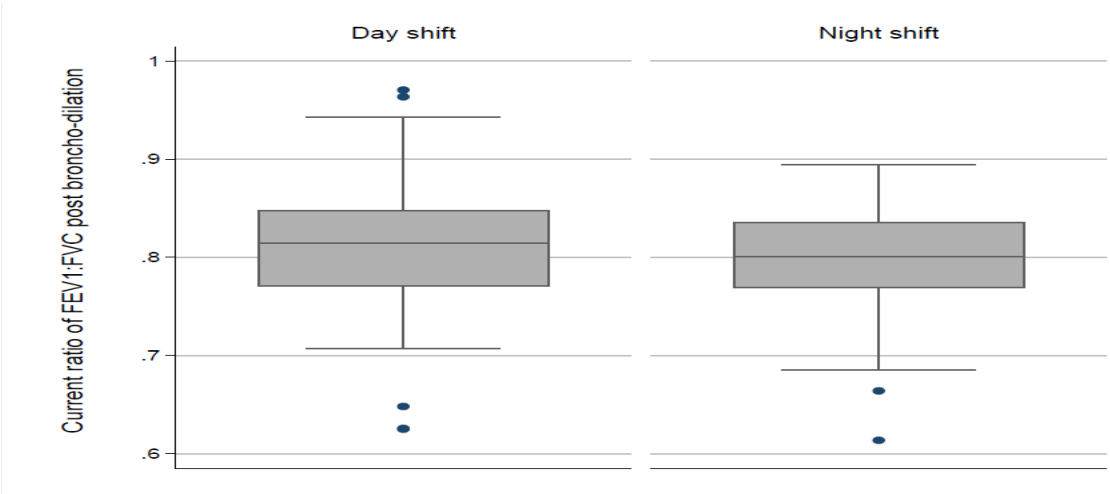

Figure 10: Box plot depicting the current ratio of FEV1/FVC with broncho-dilation for day shift and night shift.

Figure 11 compares FEV1:FVC ratios according to the type of shift.

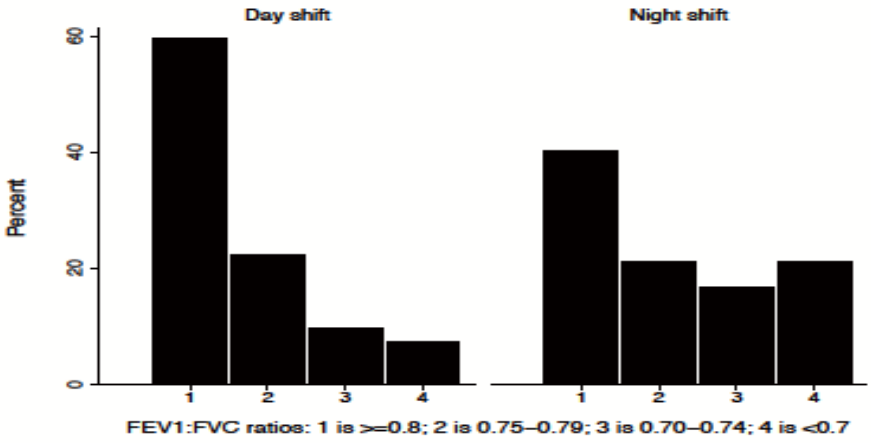

Figure 11: Frequency (percent) histograms for FEV1:FVC ratios by type of shift.

Figure 11 shows the lung function categories ranging from one (1) to four (4) as labelled on the x-axis. Each bar represent the percentage of employees within that category viz;. 60% of day shift employees had lung function at a range of 0.80+ whilst for the night shift it was 40.3% at the same category. This figure can be read in conjunction with table 7 below.

Table 7: Numbers of participants by shift and FEV1:FVC reduction (%) (No broncho-dilation)

FEV1:FVC	Day shift (n=40)	Night shift (n=47)	Total
0.80 +	24	19	43
0.75 - 0.79	9	10	19
0.70 - 0.74	4	8	12
< 0.70	3	10	13
Total	40	47	87

Table 8 below, shows FEV1: FVC ratios after repeat spirometry, while Table 9 shows the ratios for participants with non-reversible* obstruction spirometry patterns,

Table 8: Ratios of FEV1:FVC for the 14 participants who underwent repeat spirometry following broncho-dilation.

Before broncho-dilation	After broncho-dilation
0.38	0.70
0.59	0.72
0.63	0.77
0.64	0.81
0.69	**0.74**
0.70	**0.78**
0.71	0.81
0.74	0.81
0.74	**0.79**
0.74	**0.79**
0.75	0.83
0.75	**0.78**
0.75	0.84
0.75	0.89

Table 9: Ratios of FEV1:FVC for participants with non-reversible* obstruction spirometry patterns

Before broncho-dilation	After broncho-dilation
0.56	**0.69**
0.61	**0.69**
0.64	**0.61**
0.66	**0.69**
0.68	**0.63**

*Non-reversible spirometry pattern is defined for this study as having a Ratio <0.70 that does not improve to more than 0.70 following broncho-dilation

It can be seen from Table 10 that of the 14 participants, 35% did not show an improvement of >12% in FEV1:FVC after bronco-dilation administration, although 35% showed an increment of < 12% from measurements take before broncho-dilation, improved to ≥70% FEV1:FVC.

Further; none of the participants with non-reversible obstructive patterns showed an improvement in FEV1:FVC (Table 9).

Table 10 shows participants with airways obstruction from both shifts.

Table 10: Data showing number of participants with airway obstruction (divided into three categories) by shift type.[#]

Airway obstruction	Variable	Day shift (n=40)	Night shift (n=46)
Existing	a. Any kind (%) *	5 (12.5)	15 (32.6)
	b. Reversible (%) **	2 (5.3)	11 (24.4)
	c. Non-reversible (%) **	1 (2.6)	4 (8.9)
Non-existing	a. Any kind) (%) *	35 (87.5)	31 (67.4)
	b. Reversible (%) **	36 (94.7)	34 (75.6)
	c. Non-reversible (%) **	37 (97.4)	41 (91.1)

[#]Footnote:
* Number of employees who conducted spirometry (n=87**) The number is < 86 because 3 participants with obstructed airways patterns were not assessed post broncho-dilation

Obstructed lung function was shown by 23.3% of participants overall, but the day shift workers showed a considerably lower proportion (12.5%) than those on night shift (32.6%), as depicted in Table 9. Further, the tables compares the number of workers on each shift that showed reversible airways obstruction and non-reversible airways obstruction. Of the day shift participants, 5.3% presented with obstructed airway pattern when compared to the 24.4% of the night shift participants. Only 2.6% of day shift participants presented non-reversibility after the use of a bronchodilator, and 8.9% for night shift participants.

Table 11 summarises the smoking, coughing or wheeze and tuberculosis respiratory symptoms according to non-numerical variables reported by participants

Table 11: Summary statistics to describe the non-numerical variables in the samples

Variable	Day shift (n=40)	Night shift (n=46)
Current smokers (%)	11 (27.5)	12 (26.09)
Former smokers x/n (%)	2 (5.0)	6 (13.04)
Previous tuberculosis x/n (%)	6 (15.0	15 (32.61)
Currently coughing x/n (%)	6 (15.0)	19 (41.30)
Currently wheezing x/n (%)	0 (0.0)	3 (6.52)

As can be seen from the above table, there was little difference in the proportion of current smokers between the two shifts, although the level of former smokers was more than double for night shift workers (13.04%) compared to those on day shift (5%). The proportion of participants with a history of tuberculosis was also higher in those on night shift (32.61%) Than those on day shift (15%). Coughing and wheezing were also higher in the night shift workers.

Table 12 summarises the proportion of acute and chronic symptoms in day and night shift participants.

Table 12: Summary data describing symptoms.

Variable	Day Shift	Night Shift	p-value
Coughing	6/40	19/46	0.009
Coughing > 3months	0/6	14/19	0.036
Shortness of breath	-	8/19	0.257
Sputum	1/7	11/23	0.193

The proportion of workers who were currently coughing was significantly higher in night shift workers (p=0.009) and the proportion who had been coughing for more than three months was also higher (p=0.036). However there was no significant difference in the proportion of participants with shortness of breath (p=0.257) or sputum production (p=0.193), between day and night shift workers.

Table 13 shows results of logistical regression applied to data from spirometry, without broncho-dilation.

Table 13: Logistic regression results with FEV1:FVC < 0.75 as the effect variable (n = 87). (Spirometry was performed without broncho-dilation)

	Univariate regression				Multivariate regression			
Effect = FEV1:FVC ratio <0.75	OR	95%CI		p-value*	OR	95%CI		p-value†
Exposure variable:		LL	UL			LL	UL	
Shift (1 = night; 0 = day)	2.93	1.07	8.00	0.030	3.30	1.08	10.04	0.036
Age (years)	1.09	1.03	1.16	0.004	1.11	1.03	1.21	0.009
Smoke (1 = yes; 0 = no)	1.47	0.53	4.10	0.460	2.26	0.68	7.45	0.182
Years present job (years)	1.06	0.95	1.18	0.338	0.98	0.84	1.14	0.780
Ever had TB (1 = yes; 0 = no)	0.99	0.33	2.93	0.985	0.53	0.15	1.85	0.323

OR = Odds Ratio; CI = Confidence Interval; p-value = chi square p-value (*) or z-test p-value (†); LL/UL = lower/upper limit.
The continuous variables Age and Years present job were both linear in their relationships with the logit (Box-Tidwell test): Age*ln(Age) p-value = 0.102; Years present job*ln(Years present job) p-value = 0.218; Both values >0.05.
The area under the receiver operating characteristic (ROC) curve = 0.76.
The p-values for the Hosmer-Lemeshow goodness of fit test were 0.636 (8 groups) 0.464 (10 groups) and 0.852 (12 groups).

Table 14: Shapiro-Wilk test z-scores and p-values for the spirometry variables (Null hypothesis: The data are drawn at random from a normally distributed population).

Variable		Day shift (n = 40)		Night shift (n = 47)	
		z-score	p-value	z-score	p-value
FVC	Baseline	-0.47	0.681	-0.66	0.745
	Current pre broncho-dilation	-0.88	0.809	1.25	0.106
FEV1	Baseline	0.26	0.396	0.04	0.486
	Current pre broncho-dilation	0.06	0.478	-0.71	0.761
FEV1:FVC ratio	Baseline ratio	-0.34	0.633	*5.94	<0.001
	Current pre broncho-dilation	-0.61	0.729	*2.44	0.007

Baseline FEV:FVC ratio p-value = 0.633 for day shift, baseline FEV1:FVC ratio p value <0.001. There was no true baseline recorded due to the fact that even though employees worked in other mining houses before, the only baseline available was that which was recorded when they started employment at the current employer. Current FEV1:FVC ratio p value = 0.729, current FEV1:FVC ratio p value = 0.007. It

is evident that the lung function for the night shift employees taken after broncho-dilation was significant (p value of 0.007) when compared to the day shift employees which is indicative of a risk component for the night shift employees.

5. DISCUSSION

Overall 20 of the 86 workers examined showed obstructive lung patterns. The proportion was higher in night shift workers than in day shift workers, Of the 15 night shift workers with obstructive lung patterns, four showed non-reversible obstructed lung patterns. A significantly higher number of workers on night shift were currently coughing or had been coughing for > 3 months in comparison with day shift workers. Both univariate and multivariate analysis indicated that night shift workers were about 3X more likely to have a FEV1:FVC < 0.75 when spirometry was performed without a broncho-dilator.

Univariate regression tests showed that the risk of developing OAD were 3 times higher in night shift employees than the day shift employees. Most research literature which has been done on the diesel particulate matter is in reference to urban areas with high volume of diesel powered cars and railway transportation, [10] very limited studies are published in reference to trackless mining sector. Further it must also be noted that detailed studies on the effects on diesel exhaust fumes and traces of blasting fumes in an underground confined space has not been researched in the scientific literature.

The reason why night shift employees showed higher prevalence of lung decrements and/or acute respiratory symptoms needs to be explored in more detail. A possible reason is that employees may be frequently exposed to DPM that is classified as an irritant. There is evidence that chronic exposure to DPM for a longer period can result in severe respiratory effects in humans.[37] Other reason for higher exposure could be as a result of loading activity with diesel powered machines for night shift employees. Exposure to traces of blasting fumes during the night shift, due to poor ventilation and longer re-entry times, may be an additional environmental variable that may have contributed towards the higher prevalence of respiratory symptoms observed in the night shift employees.

The percentage of participants who presented with coughing was higher for night shift than it was for the day shift. The percentage of employees who had chronic cough with production of sputum was higher during night shift participants than with the day shift participants. It is very important to note that the acute symptoms were self-reported which could have resulted in some bias. The sputum was not analysed for further investigation. This requires further quantitative investigations to determine if the volume and content of sputum are different between the day and night shift. In addition, current literature indicates that chronic bronchitis is characterised by constant coughing with sputum production and it is a factor for determining obstructed lung pattern.[8]

The difference in the lung function decline for the day shift and night shift is indicative that night shift employees may be significantly more affected by workplace hazard exposure than the day shift employees. An in-depth studies on LHD drivers is required in mining industry to link the workplace hazards, exposure and health outcomes, this will ensure improvement within the occupational hygiene discipline.

Traditionally the monitoring of occupational hygiene for airborne pollutants is conducted during the day shift, this could lead to a situation where exposure levels are under estimated for the night shift employees. It was mentioned in previous studies by Hnizdo and Vallyathan [7] that the surveillance of occupational exposures and disease is weak, notwithstanding efforts of the Department of Mineral Resources to maintain registers such as the South African Mining Occupational Disease database, which was initiated in 1996.[7]

Generally; night shift employees are neglected or excluded, in terms of risk assessment. Their risk profile is therefore not representative, since their risks are ranked according to the information collected during the day shift. Again it must also be noted that there was no personal or area monitoring done in the working places during this study. This warrants more detailed studies in order to link the actual workplace hazards and the health effects, in order to further validate the outcome of this study and to add more value to the occupational health and hygiene field within the mining industry.

It should be recognised that the main activity during the day shift was drilling and blasting at the end of the shift when the employees left the working areas, while the night shift is purely loading. The workplace exposure is a function of how fast airborne pollutants are removed from the working place. During mining, general ventilation is the main engineering control used to remove pollutants from the workplace. It is therefore one of the main approaches used to provide acceptable environmental conditions during underground operations.[23] The main purpose of ventilation in underground mining is therefore to provide good quality air for the employees; and to dilute /or remove contaminants resulting from production processes.[24]

The mining industry adopted an air volume dilution factor of 0.12 m^3/s per kW ($m^3/s/kW$) in order to determine adequate ventilation requirements. This factor is used during the planning of mine design to determine the number of load haul dumps required to load in a single section. If the number of planned LHDs are exceeded, which occurs during the night shift loading, there may be an accumulation of excess diesel fumes and dust particles in the working section. This may therefore increase the risk of occupational respiratory disease in the night shift LHD operators.

Another factor which was observed during the two shifts was the allocation criteria used to dispatch the LHD's in the sections. It was observed that during the day shift there was minimal ore within the sections, as a result a maximum of two LHD's was observed in a section, however during the night shift the allocation of the LHD's was most driven by production demands. A maximum of 6 LHD's in some sections were observed during the night shift, if other sections missed the blast for the day, the supervisors tend to re-allocate some LHD's to other sections which has too much ore to be loaded which then result in non-adherence to the ventilation designs, i.e. if a section is planned at $30m^3/s$ and six LHD's are allocated in that section, the amount of ventilating air must be doubled in order to allow adequate airborne dilution.

The other major challenge during night shift was that during loading, certain ventilation holes which allow air to flow through from one section to another; became blocked, especially when the tipping points for hauling the ore became overloaded.

This process is called backlashing, and it is used in mining to store ore whilst waiting for tipping points to clear.

Poor supervision during the night shift may also be seen as a major contributor to backlashing, in addition not having a proper control on the management and allocation of LHD machineries may lead to some sections having more machines than what the ventilation design requires. These activities during the night shift, may lead to accumulation of airborne pollutants and compromise employee's health. It was observed that during night shift the employees did not follow the correct dust allaying methods. To elaborate on this, we observed that during the night shift the employee's only water down the ore which is on top, thereafter they load the ore continuously without suppressing the dust which is trapped on the surrounding bigger rocks or fine dust underneath.

During day shift all the sections are planned to have a supervisor. The role of the supervisor is to inspect the workplace hazard which is carried out during early entry examinations by the miner and his team before they start any work. The supervisors also assist in ensuring safe production by conducting planned task observation to ensure that employees are working safe. During night shift this function is highly compromised and safe production cannot be guaranteed.

Employees on night shift may also be at risk of being exposed to traces of blasting fumes, and respirable dust which becomes airborne, due to failure to comply with the re-entry period or poor watering down to supress dust after the blast. As a result of poor supervision it may be possible that employees carry on loading without supressing the dust. These aspects require further investigation.

It must also be noted that dust mask are used to protect the employees from being exposed to dust, is a dust mask adequate to prevent employees from being exposed to diesel particulate matter? One needs to explore if the risk assessment conducted warrant the use of dust mask as a proper or adequate control for DPM. Further, during the night shift it was observed that due to amount of fumes and dust generated from loading, one (1) dust mask was not adequate for the whole shift as it quickly became clogged with black residues and dust particles making it difficult to breath.

The reversibility of obstructive lung patterns, was tested by the administration of a bronchodilator to the participants. A bronchodilator plays an important role in the pharmacological treatment of obstructive airway disease, because it physiologically reverses airflow obstruction by relaxing smooth muscle in the airways and improving lung emptying during tidal breathing.[25] After the post broncho-dilation was conducted; the day shift employees still showed an obstructed lung pattern and a significant higher amount of night shift employees presented an obstructed lung pattern (Table 13). On average the night shift employees presented non-reversibility on the lung function after the use of a bronchodilator. This clearly shows that the night shift employees are at a higher risk for OAD.

Literature shows that an increment of FEV1 of ≥12% from the pre-measurement indicates a possibility of asthma. The measurements which were conducted after the administration of a broncho-dilator showed a substantial higher number of improvement above 12%. However it was also observed that a number of measurements were below 12% improvement criteria for reversibility, an indicator of chronic obstruction airway disease. A reduced FEV1 and an absolute FEV1/FVC ratio indicates an obstructive ventilatory pattern and bronchodilator challenge testing is recommended to detect patients with reversible airway obstruction (e.g., asthma).[26] The test is positive if the FEV1 increases by at least 12 percent and the FVC increases by at least 200 mL. A requirement is that the patient should not use any bronchodilator for at least 48 hours before the test. [26]

It is evident from Table 7 that 35% of the 14 employees showed an obstructed lung pattern and underwent broncho-dilation. The FEV1/FVC ratio was less than 12%, which raises the possibility of reduced FEV1. This may be a sign of obstructed lung pattern, even with an indication of reversibility. It needs to be emphasized that a detailed study to explore the improvement shown in FEV1, FVC and the ratio is required when a broncho-dilation challenge is used in order to best understand the risk components for OAD or asthma. From the literature review we are certain that DPM, and possible blasting fumes, are irritants which can sensitize the employees with low dose exposure over a prolonged time period and puts them at risk of developing asthma or OAD. Further studies may be needed to quantify these aspects, in order to confirm the published literature.

The regression analysis showed that the participants from the night shift had more than 3 times the odds of an obstructive airways pattern on spirometry (after comparison to those in the day shift). This odds ratio remained over 3 after disaggregation into the type of obstruction (reversible or not) and also after adjustment for possible confounding factors such as age and smoking. This odds ratio increased to over 6 for the outcome reversible obstruction. The outcome for non-reversible obstruction was not modelled due to the small number of participants (four in the night shift and one in the day shift) who were positive for non-reversible airways obstruction on spirometry. The post regression tests show that the models are predicting the observed outcomes quite accurately and that gives confidence in the final results.

The results also show that the ORs for smoking, past TB, age and duration of exposure were not statistically significant. The study was designed to measure the effect of airways obstruction of LHD driver working on the night shift in comparison to the day shift. The prevalence of smoking, past tuberculosis and duration of previous employment was similar in both exposure groups for current smoking (day shift 11/40 vs. night shift 12/46) and for age (37.43 for the day shift and 38.23 for the night shift). However there were quite large differences in the other two variables. Among the night shift participants 32.61% had past tuberculosis while this percentage for the day shift workers was 15%. There was a small difference in the number of years in the current job, namely 6.63 years for the day shift and 5.72 years for night shift workers.

The diagnosis of obstructive airway disease relies on reliable diagnosis, occupational exposure and chronological relationship between exposure and outcome.[18] The variables of interest when measuring the lung function for FVC and FEV1 are calculated from equations based on age, height, gender and ethnic group because these characteristics are the most important determinants of lung and airway size in healthy individuals.[13,14,15] For this study the AME spirometer was used, which is used by the mine clinic to measure and manage spirometry results during entry, periodical and exit medicals.

For the purpose of the study AME Spirometry was used, however, with the AME spirometry we could not get information on the mathematical modelling they use for adjusting for the black ethnic males, as has been suggested by Louw. [20] It was therefore not confirmed whether the obtained results were corrected; if the results were not corrected for ethnicity, this could have affected the reliability of the measured results. Although only black males were used, it may be regarded as a limitation in this study.

Other limitations could have been that the actual exposures to DPM and mineral dust were not measured to quantify the exact exposure concentrations. This could have been an important variable to link to the declining lung function with exposure. Information bias might have affected the reporting of the symptoms such as coughing and sputum production. In most instances the employees working night shift are separated from their families, this might affect them socially; as a result they could have reported having symptoms with a hope of being changed to the day shift.

It must also be noted that spirometry is effort based, if an employee is not willing to take the measurement it becomes difficult to get useful representable results. In addition determining a decline in lung function by means of spirometry can be a lagging indicator, which means that detailed workplace investigations, sputum analysis, COPD assessment test and the Medical Research Council dyspnoea scale (MRC) breathless test should form part of the diagnosis during routine medical review.[25,27]

6. CONCLUSION AND RECOMMENDATIONS

In conclusion, night shift LHD drivers presented a marked reduction on the lung function as well as acute and chronic respiratory symptoms. Night shift LHD drivers may therefore be at risk of developing obstructive airway disease due to higher concentrations of diesel particulate matter, mineral dusts and other airborne pollutants. The increased risk may be attributed to diesel particulate matter (from loading) and traces of blasting fumes.

Occupational hygiene systems should incorporate the measurements of airborne pollutants during the night shift; taking into consideration the ventilation design and minimum air quantity requirements as well as Personal Protective Equipment (PPE), which is a last resort control measure. In addition, although PPE is the last resort in terms of protecting the employees, in cases where it is used as a control a proper risk assessment must be conducted to determine if the PPE is appropriate for the job. One would ask a question to say: Is a dust mask proper PPE to prevent exposure to diesel exhaust fumes? These questions must be answered in order to better manage personal total exposure.

Traditionally the measurements are taken during the day shift, which does not represent the worst case scenario. Follow up studies should be include comparison of actual workplace airborne exposure for both day and night shift versus the lung function decline. This information is very critical in the mining industry where trackless diesel powered machinery is used to strengthen monitoring and prevention strategies for employees working night shift. Ehrlich et al [2] explained in their studies that although COPD is preventable, it could increase in South Africa, unless measures are put in place to prevent smoking and occupational exposures are decreased through health counselling. The South African mining industry needs improved occupational hygiene systems and appropriate supervision. Based on observations, the following improvements are recommended:

- Medical surveillance must be of good quality and yield reliable results.
- Occupational hygiene measurements of airborne pollutants need to be conducted during night shift to accurately quantify the risk at night.
- Ensure proper management of risk based medical surveillance for LHD drivers is in place.
- Ensure lung function technicians apply proper control measures during the assessment of lung function so that real cases are not missed.
- Ensure that the type of a spirometry used to measure lung function incorporate the corrective factor such as individual’s height, gender and ethnic group for correct predictive values of FEV1 and FVC.
- Disciplinary measures to be taken into considerations especially with the compliance to the ventilation design requirements.

- Optimisation of energy resources through active control and predictive simulation modelling for ventilation to establishing a safe, healthy and productive working environment in mechanised underground mines.
- Conduct the studies to cover all different seasons and also in different types of mining such as board and pillar, hybrid mining and conventional mining.

7. LIMITATIONS

The study was a descriptive study, which requires a larger sample size in order to have a proper prevalence report. Originally the study intended to compare the risk of outcome for day and night shift LHD drivers in both chrome and platinum mine. As the chrome mine was not included, this resulted in a smaller sample size.

An AME spirometry graph was utilised at the mine clinic to measure lung function, the equation to determine spirometry made use of the Caucasian ethnic group standard, nowhere was is stated that when testing for African black males the figures should be corrected using a factor of 0.9. This specific factor need to be validated for AME spirometer so that we are certain with the validity of the predictive values for FEV1, FVC and the ratio.

Spirometry is dependent on the participant undergoing the test or measurements, i.e; it is effort based and when used alone to determine obstructive airway disease it can result in unreliable information being reproduced.

Initially the study aimed at classifying the severity of the chronic obstructive airway disease using the Global Initiative for Chronic Obstructive Lung Disease (GOLD) staging classification. However more recent studies. [27,28] have indicated that the GOLD classification rules have been revised since the 2011 COPD guidelines; the new COPD Assessment tool and the Medical Research Council dyspnoea scale (MRC) that evaluates breathlessness, are utilised together with predicted spirometry values to classify COPD for correct collection and reporting of symptomatic data.

The study was conducted during winter i.e. from April month to July, this could have added a negative influence on the employee's lung function in instances where

employees had infections such as bronchitis or flu and cough due to lower temperatures in night shift. A study to cover all seasonal periods to ensure that the underground environment is correctly modelled is required to determine the possible impact of seasonal variation.

Again the study was prevalence study design and only took a snapshot of the health outcomes of the LHD drivers. It would be beneficial to consider conducting the study in a longitudinal study design over a longer period of time to observe the different environmental conditions and whether the concentration of the airborne pollutants is affected by the thermal changes, comparing the environmental conditions in different types of mining design such as board and pillar, hybrid mining and conventional mining as well as the effects of health outcome (lung function) during the different seasonal periods.

Actual velocities and quantities in the workplace during the study was also not recorded. Further studies is required to map all the available air quantities in different areas to justify if working outside the required ventilation design requirements has an effect to the direct or personal exposure to the employees.

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Addendums A1 – Informed Consent and Research Questionnaire

PARTICIPANT'S INFORMATION LEAFLET & INFORMED CONSENT FOR ANONYMOUS QUESTIONNAIRES

Amukelani Portia Manyike

Student Number: 10550969

Department: School of Health Sciences and Public Health

University of Pretoria

Dear participant,

A Descriptive Study to Determine the Prevalence of Chronic Obstruction Airway Disease amongst Load Haul Drivers (LHD) in Trackless Mines

I am a Master of public health student in the school of health sciences and public health department, University of Pretoria. You are invited to volunteer to participate in my research project on A Descriptive Study to Determine the Prevalence of Chronic Obstruction Airway Disease amongst Load Haul Drivers (LHD) in Trackless Mines

This letter gives information to help you to decide if you want to take part in this study. Before you agree you should fully understand what is involved. If you do not understand the information or have any other questions, do not hesitate to ask me. You should not agree to take part unless you are completely happy about what we expect of you.

This research study aims to find out if LHD drivers are at risk of developing lung diseases as a result of breathing dust and diesel smoke when they are at work. This research project is funded by the Xstrata Alloys. Through your participation, I eventually hope to understand how best to design a surveillance program that will identify and manage the risk of long-term lung diseases.

I would like you to complete a questionnaire. This may take about thirty (30) minutes. I will collect the questionnaire from you before you leave the occupational hygiene offices. The questionnaire will be kept in a safe place to ensure confidentiality. If you choose to participate, please write your company number on the questionnaire. Your company number will be matched with a specific unique number; this unique number will identify you throughout the study. Your company number is only used by the occupational health practitioner to obtain your baseline lung function results. After the baseline lung function results were obtained, your company number will be deleted with a permanent marker, only your unique number will be left to identify you. Nothing you say on the questionnaire will in any way influence your present or future employment with your company.

As part of the study; I would also like you to take part in lung function at our Xstrata occupational health clinic. If the results of your lung function are below 70%, you will be asked to perform a second lung function at the administration of a bronchodilator. All participants with III and IV Gold classification will be referred to the OMP of the mine.

I will be available to help you with the questionnaire or to fill it in on your behalf. Note that if there are questions that are sensitive to your nature you are welcome not to answer them. Your participation is voluntary and there is no penalty if you do not participate or choose not to answer some questions.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences granted written approval for this study. Your participation in this study is voluntary. You can refuse to participate or stop at any time without giving any reason. Since your company number is required to obtain your baseline lung function, your company number will be deleted to maintain confidentiality once you have completed your lung function; the questionnaire will only reflect the unique

number that will prevent us from tracing your information. Therefore, you will not be identified as a participant in any publication that comes from this study.

Note: The implication of completing the questionnaire is that informed consent has been obtained from you. Thus any information derived from your form may be used for e.g. publication, by the researchers.

I sincerely appreciate your help.

Yours truly,

Amukelani Portia Manyike

SECTION A - DEMOGRAPHICS

Company number	
Unique study number (to be completed by investigator)	

1. Date of interview

d	d	m	m	y	y
date		**month**		**year**	

2. Sex (Mark with X)

Female ☐ **Male** ☐

3. Date of birth

d	d	m	m	y	y
date		**month**		**year**	

4. Height	m
5. Weight	kg

SECTION B - SOCIAL AND WORK INFORMATION

6. Are you a Smoker? (Mark with X) Yes ☐ No ☐

7. Number of cigarettes per day ☐

8. Ex-smoker - When did you stop smoking? Yes ☐ No ☐

9. Total years of smoking ☐

10. Job title ☐

11. Provide the date you were employed in the current position? ☐

12. How many hours do you work per day ☐

13. Are you exposed to diesel fumes at work (Mark with X) Yes ☐ No ☐

SECTION C – MEDICAL HISTORY

14.1 Date of lung function baseline at Xstrata

(To be completed by OHP)

d	d	m	m	y	y
date		**month**		**year**	

14.2 FEV1 at baseline

(To be completed by OHP)

	%

14.3 FEV1/FVC at baseline

(To be completed by OHP)

	%

15. Most recent lung function date

(To be completed by OHP)

d	d	m	m	y	y
date		**month**		**year**	

15.1 Pre FEV1 %

(To be completed by OHP)

15.2 Post FEV1 %

(To be completed by OHP)

16.1 Have you ever been treated for lung tuberculosis? **Yes** ☐ **No** ☐

16.2 If yes, What year?

d	d	m	m	y	y
date		**month**		**year**	

17. Do you experience the following symptoms?

17.1 Coughing **Yes** ☐ **No** ☐

17.2 Does your cough hurts? **Yes** ☐ **No** ☐

17.3 Does your cough makes you tired? **Yes** ☐ **No** ☐

17.4 Does your cough disturb your sleep? **Yes** ☐ **No** ☐

17.5 Is your cough accompanied by sputum? **Yes** ☐ **No** ☐

17.6 Did your cough last more than 3 months in any year?	**Yes**	☐	**No**	☐
17.7 Do you experience difficulty in breathing?	**Yes**	☐	**No**	☐
17.8 Wheezing	**Yes**	☐	**No**	☐
17.9 If you wheeze, is it worse in the morning?	**Yes**	☐	**No**	☐
17.10 Do you experience respiratory acute infections?	**Yes**	☐	**No**	☐
17.11 Do you experience phlegm?	**Yes**	☐	**No**	☐

17.12 Do you experience shortness of breath?	**Yes**		**No**	
17.13 Did your chest problem interfere with your job?	**Yes**		**No**	
17.14 Have your chest problems causes you to be absent from work at times?	**Yes**		**No**	

18. <u>At what time does you experience breathlessness?</u>

18.1 When you start your shift?	**Yes**		**No**	
18.2 When you finish your shift?	**Yes**		**No**	
18.3 During the shift?	**Yes**		**No**	

Thank you for your co-operation in completing this questionnaire.

Addendum A2 – Letter of permission from employer

Date 04 Sept 2012
Mr. : J Combrink
General Manager Xstrata Eastern Chrome Mines

Address: Thorncliffe farm, Portion 1
Route R557
P.O. Box 402
Lydenburg
1120 , SA

RE: Permission to Conduct Research Study – **A cross-sectional study to determine the Prevalence of chronic obstruction Airway disease amongst Load Haul Drivers in Trackless mine**

Dear Mr. J Combrink

I am writing to request permission to conduct a research study at your Mine. I am currently enrolled in the Masters degree of Public Health at Pretoria University and am in the process of writing my Master's Dissertation; ***the study is entitled A cross-sectional study on the Prevalence of chronic obstruction Airway disease amongst Load Haul Drivers in Trackless mine***. The purpose of the study is to determine the frequency of long-term lung diseases amongst LHD operators in trackless Mines; I eventually hope to understand how best to design a program that will identify and manage the risk of long-term lung diseases.

I hope that you will allow me to recruit all your LHD operators from the Mine to anonymously complete a questionnaire and to conduct a lung function test. Interested LHD operators, who volunteer to participate, will be given a consent form to sign and to return to me at the beginning of the survey process. The study will take approximated period of four months.

If approval is granted, LHD operators will be paraded to complete the questionnaire and to conduct lung function at the Xstrata/Life site clinic. The operators will be

paraded for the second time for another lung function at the administration of a bronchodilator if the first tests produce an FEV1 of less than 70% to determine if the obstruction is reversible. After conducting the tests the operators will proceed to work where they will continue with their daily duties. The survey process should take no longer than two hours. The survey results will be pooled for the dissertation project and individual results of this study will remain absolutely confidential and anonymous. Should this study be published, only pooled results will be documented. The cost of lung function will be incurred by the Mine during the survey.

Your approval to conduct this study will be greatly appreciated. I will be happy to answer any questions or concerns that you may have, you may contact me at my email address:_amodau@xstrata.co.za.

If you agree, kindly sign the form below with your institution's letterhead acknowledging your consent and permission for me to conduct this survey/study at your Mine.

Sincerely,

AP Manyike,

University of Pretoria

xstrata
alloys

Tel +27 13 230 6600
Fax +27 13 230 6502
Email
Web www.xstrataalloys.com

Address Xstrata Alloys
Eastern Chrome Mines
Thorncliffe Farm, Portion 1
Route R557
PO Box 403
Lydenburg, 1120
South Africa

Title: *A Cross-sectional study to determine the Prevalence of chronic obstruction Airway disease amongst Load Haul Drivers (LHD) in Trackless mines.*

Approved by: General Manager

J.H. Combrink | | 4/09/12

Print your name | Signature | Date

Addendum A3 – Research Protocol

University of Pretoria

Faculty of Health Sciences

School of Health Sciences & Public Health

A Descriptive Study to Determine the Prevalence of Chronic Obstructive Airways Disease amongst Load Haul Drivers (LHD) in Trackless Mines

For the degree (MPH)

Author: Amukelani Portia Manyike

Student Number: 10550969

Contact Details

Address: Xstrata Merafe, Eastern Chrome Mines, Thorncliffe Portion 1, Prov Route R577 Steelpoort, PO Box 403, Lydenburg, 1120, South Africa

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Supervisor: Dr N Claassen – SHSPH

Co-Supervisor: Prof B GirdlerBrown – SHSPH

Date: 30 April 2012

A Descriptive Study to Determine the Prevalence of Chronic Obstructive Airways Disease amongst Load Haul Drivers (LHD) in Trackless Mines

Abstract: During the day to day mining activities miners are exposed to different airborne pollutants which may result in occupational lung diseases (OLDs). In South Africa there is high activity of industrialization where mining is a primary activity of that industrial base. Mine related lung diseases depends on the type of commodity that is mined, size of airborne pollutants, exposure time, environmental conditions as well as the employee's life style. The aim of this study is to determine the prevalence of chronic obstruction airway disease (COAD) amongst LHD operators working in trackless mines. The study will be conducted in two different mines *viz*; platinum and chromite mines in Mpumalanga. The study population will be underground LHD operators who are frequently exposed to mineral dust and diesel particulate matter (DPM) during loading and off-loading of raw minerals. Spirometry will be conducted to determine their Forced Vital Lung Capacity (FVC) and the Forced Expiratory Volume 1 (FEV_1): both before and after bronchodilation. Subjects will also be required to complete a questionnaire to obtain information on their demographics; self-reported social and health history, including respiratory symptoms. The severity of the chronic obstructive airway disease will be categorised and presented using the Global Initiative for Chronic Obstructive Lung Disease (GOLD) staging classification. In conclusion the obtained prevalence information may be used by the mines to design an evidence based medical surveillance program to monitor and manage the airborne particulate matter exposure level to prevent COPD if necessary.

1 Literature Review

1.1 Introduction

Occupational injuries and ill-health have huge social and economic implications for individuals, their families and their communities [1]. This is due to the fact that employees become medically incapacitated and they can no longer provide for their families and communities because of ill health and the costs involved towards their health. Exposure to mineral respirable dust has long been linked to respiratory disease in the mining industry [2,3,4]. In addition, exposure to diesel particulate matter (DPM) due to trackless diesel powered machines may add to the toxicological burden on the lungs of the LHD operators. It may therefore be required to include DPM as a variable that is responsible for respiratory diseases in mining industry reported today. Epidemiology indicates that during the period 1973 to 1993 (20 years) the Mineral Bureau for Occupational Disease certified 128 575 cases of occupational lung disease [1]. Hermanus [1] also indicates that the cases may be under estimated since the majority of black workers who were exposed to respirable dust were not previously entitled to the benefit of examination.

1.2 Chronic Obstruction Airway Disease

Chronic obstructive airway disease is characterized by the gradual progression of irreversible airflow obstruction and increased inflammation in the airways and lung parenchyma that is generally distinguishable from the inflammation caused by asthma [6]. Patients with COAD present with a variety of clinical findings, including elements of chronic bronchitis and emphysema [7]. The cells that are associated with COAD are the alveolar macrophages, neutrophils, and cytotoxic $CD8^+$ effector T Lymphocytes. These cells develop progressive infiltration into the parenchyma, results into mucus production, destruction and pathological airways of the extracellular matrix of the alveolar walls and lung tissue leading to emphysema [8]. COPD can be diagnosed using the method of airflow limitation and is best measured

by spirometry, before and after bronchodilation (to exclude asthma) as this is the most widely available reproducible test of lung function [6].

1.3 Risk Factors

The primary cause of COPD is said to be amongst people who smoke [8]. However, previous studies indicate that about 94% cases in the United States occur amongst current or former smokers [5]. On the other hand, studies also indicate that exposure to dusts and other irritants may account for some occurrence of COPD. Louis [5] explains that tobacco smoke exposure and COPD predominantly comes from population-based studies that have consistently shown that smoking is associated with diminished lung function, more frequent respiratory symptoms, and increased COPD-related deaths. Lee and Fry [9] also indicates in their studies that amongst the people who continue smoking there is an average rate of decline in FEV1 that is substantially greater than that of people who have never smoked.

In mining, the cutting, breaking, crushing, drilling, grinding or loading of ore and surrounding rock produces airborne respirable dust [4]. The drilling or cutting of the rock is followed by blasting of the rock at the end of the working shift. During blasting fine dust is generated and is carried away by the ventilating air stream throughout the mine and exhausted by the main surface fans. However a large quantity of dust is trapped with the rock that is broken by blasting. Some of the coarse particles that became airborne during blasting settle out on the footwall. If precautions such as watering down before loading are not taken, these settled particles can become airborne and can be inhaled by the LHD operators after blasting [4]. Miners may develop various occupationally-related respiratory diseases including COPD based on the materials they work with and how much exposure they have had to them, in addition COPD is a feature that is found in silicosis cases [2,3,4].

1.4 Respirable dust

Respirable dust is defined as particles which are less than 10 micrometers in diameter and cannot be seen with the naked eye. Information available on exposure to airborne health hazards suggest that, depending on the commodity under consideration, between 9 and 50 per cent of exposed workers, who account for about half of the workforce, are overexposed to airborne pollutants [2]. Airborne respirable dust that is inhaled by miners can be deposited in the lungs and cause damage to the lung tissue.

In the mining sector a number of studies have been conducted in regards to COPD and silica dust exposure as well as at platinum refinery plants. Previous epidemiological studies show that silica dust exposure can lead to airflow obstruction in the absence of radiological signs of silicosis [5]. Literature on the direct health effects associated with raw chromite and platinum ore are however limited. In platinum and chromite mining operations, the silica quartz content of the ore is often low and exposure measurements in South African mines indicated that operators are exposed to low levels of respirable crystalline silica [4,10]. However, the association between cumulative silica dust exposure and airflow obstruction can be independent of silicosis [7]. In silica dust exposed workers, lung fibrosis and pulmonary tuberculosis can contribute to airflow obstruction [3]. The focus areas has been based on the effects of silica dust, hence a lot of studies was conducted in the gold mines where the concentration of silica has been known to be significant.

A study that was conducted in 1968 by Sluis-Cremer and Du Toit [10] highlights that there may be a link between emphysema and chronic bronchitis amongst workers in chromite mines. They referenced previous studies where it was reported that similar symptoms were also observed in animal studies. However, there was no fibrosis observed with the reported animal studies. This study was conducted in the Transvaal Province after ten chromite miners in South Africa were found to show radiological evidence of fine nodulations, amongst the ten, five of the miners had only worked in chromite mines.

1.5 Diesel particulate matter

LHD operators are not only exposed to air borne dust during loading, they are also extensively exposed to DPM due to the utilisation of diesel powered machines in the underground mining environment. DPM is defined as a sub micron (< 1.0 micron) physical aerosol component of diesel exhaust which is made up of solid carbon particles. It is composed of vapors, gases and fine particles [11]. DPM are suspected to be a risk factor towards occupational asthma because it is an irritant which can induce inflammation, however a study by Adewole et al indicates that exposure to DPMs at 200 $\mu g/m^3$ can cause sputum neutrophilia, without changes in Forced expiratory volume in 1 second (FEV_1) [12]. Furthermore, there has not been an identified link between DPM exposure and COAD. On the other hand, smoking may act as a confounder because literature indicate that smoking is the main cause of COPD, this means that when diagnosing COPD at occupational level, results must be carefully analysed where occupational exposures are involved.

1.6 GOLD Scores

Spirometry is used for diagnosing and monitoring the progression of COPD [6].The American Thoracic Society has developed the GOLD (Global Initiative for Obstructive Lung Disease) scores for COPD in order to be able to classify the severity of non-reversible airflow obstruction. When measuring spirometry, sex, age, height, and population group is taken into consideration in order to compare the FEV_1 and FVC with the reference or predicted values of a healthy person of the same sex, age, height and population group. The symptoms related to COPD are also recorded in order to make the final classification of the disease; these will include coughing, increased sputum production and dyspnea [13,14]. The questionnaire of symptoms is attached as addendum A, this will be used to collect information from the subjects before they proceed with spirometry tests. In addition, table 1 below consists of clinical features which will be used as a guide to differentiate between COPD and Asthma amongst the tested subjects.

Table 1: Clinical Features Useful in Differentiating COPD from Asthma [13].

Clinical feature	COPD	Asthma
Age	Older than 35 years	Any age
Cough	Persistent, productive	Intermittent, usually non-productive
Smoking	Typical	Variable
Dyspnea	Progressive, persistent	Variable
Nocturnal symptoms	Breathlessness, late in disease	Coughing, wheezing;
Family history	Less common	More common
Atopy	Less common	More common
Diurnal variation in symptoms	Less common	More common

1.7 Diagnostic Tools

The diagnostic tool that will be used is a combination of spirometry and questionnaires. Spirometry is used to measure air flow in the lungs. Lee and Fry [4] describe FEV1 as a marker of chronic obstructive lung disease, since called COPD. In GOLD COPD, classifications are used to describe the severity of the obstruction or airflow limitation. The worse a person's airflow limitation is, the lower their FEV1 [6]. As COPD progresses, FEV1 tends to decline. GOLD COPD staging uses four categories of severity for COPD, based on the value of FEV1 [6] as well as the presence or absence of specific respiratory symptoms.

The outline of the questionnaire will be divided as follows: clinical history, demographic history, and work history. In addition to this, pre- and post-bronchodilator spirometry will be measured to determine the FVC and FEV_1.

Table 2: Spirometric GOLD Classification of COPD Severity Based on Post-bronchodilator FEV1 [8].

Stage	Description	Predicted values (based on postbronchodilator FEV1)
0	At risk	Risk factors and chronic symptoms but normal spirometry
I	Mild	FEV1/FVC ratio less than 70 percent FEV1 at least 80 percent of predicted value May have symptoms
II	Moderate	FEV1/FVC ratio less than 70 percent FEV1 50 percent to less than 80 percent of predicted value May have chronic symptoms
III	Severe	FEV1/FVC ratio less than 70 percent FEV1 30 percent to less than 50 percent of predicted value May have chronic symptoms
IV	Very severe	FEV1/FVC ratio less than 70 percent FEV1 less than 30 percent of predicted value or FEV1 less than 50 percent of predicted value plus severe chronic symptoms

Predicted values for FVC and FEV1 are calculated from equations based on age, height, gender and ethnic group because these characteristics are the most important determinants of lung and airway size in healthy individuals [14,15,16]. These values were derived from scientific studies of the Caucasians, such as the European Community for Steel and Coal (ECSC). Amongst the South African research studies, Louw [16] studied the South African male population which indicated that between African black and white males there were differences with the size of their lungs; black males showed to have small lungs when compared to the white males of the same height and age due to the limb length to chest ratio. As a result; the predicted values for the black males is adjusted with a specific factor in order to obtain normal spirometry results, the South African Thoracic Society standards of spirometry committee use a factor 0.9 which is substituted to equations to get the corrected reference values [15] . COPD staging is categorized from stage

0 (for at risk individuals) through to stage IV (individuals at severe stage), However for the at risk population GOLD [14] indicates that there are no conclusive studies that governs stage 1, therefore it is normally omitted when listing the GOLD staging.

2. AIMS/OBJECTIVES

1. To determine the prevalence of COPD amongst LHD drives occupationally exposed to mineral dusts and diesel particulate matter in trackless mines.
2. To determine the relationship of selected epidemiological determinants on the status of COPD in the LHD drivers, further day shift and night shift employees will be compared for the severity of the lung function decline and to determine whether a difference exists between employees that work only day and night shift

3. METHODS AND MATERIALS

The study population will be LHD operators at two trackless mines. The objective of the study will be explained to the subjects. Informed consent will be requested from the LHD operators after explaining the objectives and all relevant procedures of the study. A questionnaire to capture demographic information, clinical information regarding respiratory signs and symptoms, social habits and work environment will be obtained by means of direct interview prior to the spirometry measurements. A trained clinical nurse will be dedicated for spirometry and administration of a bronchodilator to the LDH drivers. Spirometry will be performed according to the SANS 451:2008 and ATS – ERS 2005 Spirometry standards [17,18]. The measuring instruments for the lung function will be calibrated according to standard; SANS 451:2008 and calibration certificates will be submitted. In addition to the information above:

- Study population: 400 LHD divers in the study will be divided into two groups; those who are exposed to chromite (n = 200) dust and those to platinum dust (n = 200).

- Each employee will undergo a spirometry test to determine the FCV and FEV1.
- The weight will be measured with the subjects wearing light clothing and barefoot on a weighting scale. The standing height will be measured without shoes with the subject's back to a vertical backboard.
- For subjects with FEV_1 of less than 70%, a second spirometry will be performed after a week with the administration of a bronchodilator.
- A fixed format will be used to log the interview questions as well as the spirometry results.
- Three copies of the collected data will be generated; they will be distributed to the participant, participant's file and a research file respectively.

The following variables will be controlled to ensure the quality of the results:

- Participants will be coached on how to perform a spirometry prior the tests.
- The participants will be allowed to blow spirometry three times to produce reproducible results. If the results are not reproducible participants will be allowed to continue blowing the spirometry with a limit of 8 attempts, more than 8 attempts will not be accepted and the results will be discarded [17,18].
- The highest measurement of the set only will be used.
- Employees will be allowed a second spirometry test after a week.
- Factors that can influence the spirometry tests such as coughing, hesitation, obstruction of mouse piece and leak around the mouth piece will be observed by the researcher during the measurements to ensure quality results.

3.1. Analysis of the results

- Data will be entered twice into Epidata to ensure correct data entry. There after it will be exported to Stata version 12 for analysis.
- The spirometry readings will be used to derive membership of GOLD categories. The resulting data will be in the form of count data of the numbers in each category.

- Descriptive and demographic data will be presented as histograms, pie charts or in table form as appropriate.

4. ADMINISTRATIVE ASPECTS:

4.1. Ethical aspects

- The Mine will give permission in writing to conduct the research at their institution; the letter will outline all the aspects to be addressed on the study. A signed document will be submitted together with the final protocol.
- A signed consent will be taken from the participant to volunteer in the study; the consent will be explained to the participant prior the participation.
- The signed consent will be verbally interpreted in the employee's language for understanding.
- The participant will not receive any payment or other compensation for participation in this study, it will be a fairly voluntary participation.
- Information that can identify the participant individually will not be released to anyone outside the study including the employers. Any information we use for publication from the study will not identify the participant individually.
- Confidentiality will be maintained by means of a unique number. We will not use the participant's name in any of the information we get from this study or in any of the research reports. When the study is finished, we will destroy the list that shows which unique number goes with the employee's name and company number.
- If the participants volunteer to be in this study, they may withdraw at any time without consequences of any kind. They may also refuse to answer any questions they do not want to answer. There will not be any penalty if they withdraw from the study and they will not lose any benefits or current job to which they are otherwise entitled.
- If the results show that a participant has COPD, the name of the employee will not be revealed to the employers, the results from the study will be to assist the Mines to implement a proper medical surveillance program and awareness with the aim to improve health of the employees. In addition, the

outcome of the study will not have an effect on the employment income of the employee.

- However if miners have been classified as being grade III and IV in terms of GOLD category, they will receive a copy of their results and referred to the appointed mine OMP, furthermore; the OMP may still refer the miners to the specialist at NIOH for further tests which will determine if a miner is suitable for a compensation claim and a standard procedure which is followed by the mine for all occupational disease will be adhered to.
- All miners are inducted annually on symptoms of COPD and control procedures implemented at the mine to reduce their exposure.

a. Budget

The equipment are readily available.
Unit Cost of a lung function is R42.00
Number of LHD considered for the study is (n) = 400
Each employee will be allocated a budget of two lung functions
Estimated Total cost then = R84 *400
= ±R33600.00
Equipment will be calibrated before measurements commences.
All costs involved will be carried by the mine.

b. Project team

Author	Mrs. AP Manyike	- University of Pretoria - SHSPH
Supervisor	Dr. N Claassen	- University of Pretoria – SHSPH
Co-Supervisor	Prof B GirdlerBrown	- University of Pretoria - SHSPH
Statistician	Prof B GirdlerBrown	- University of Pretoria - SHSPH

2. ACTION PLAN

Table 1: Action Plan

ACTIONS	Responsible person	Time	Budget	Action Specification
Literature study	AP Manyike	Jan –Apr 2012	N/A	Review published materials
Draft protocol	AP Manyike	January-April 2012	N/A	Writing relevant gathered information
Statistics	Prof GirdlerBrown	May 2012	N/A	Finalize with Prof Girdler Brown
Ethics	student ethics committee	October 2012	N/A	Final protocol to be submitted to student ethics
Data capturing	AP Manyike	November 2012 to January 2013	N/A	Measurements to be captured
Data analysis	Prof GirdlerBrown & AP Manyike	March 2013	N/A	Statistical analysis of measured data (comparison).
Draft report	AP Manyike	Ongoing	N/A	Draft report is being generated as information is captured.
Final Report	AP Manyike	April 2013	N/A	All information to be refined for the final report
Publishing	Dr Claassen AP Manyike	May 2013	N/A	Final article to be published.
Conference	AP Manyike			

Table 2: GANTT CHART

ACTIONS	Jan 12	Feb 12	Mar 12	Apr 12	May 12	Jun 12	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13
Literature study	----	----	----	----										
draft protocol	----	----	----	----										
Statistics					----									
Ethics					----	----								
Data capturing								__	___	___	___			
Data analysis												----		
Draft report	----	----	----	----	----	----	----	----	----					
Final Report									----	----		----	----	
Publishing										----				-----
Conference														

3. REFERENCE

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Addendum A4: Ethical clearance

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

17/10/2012

Number	:	**S178/2012**
Title	:	A Descriptive Study to Determine the Prevalence of Chronic Obstructive Airways Disease amongst Load Haul Drivers (LHD) in Trackless Mines
Investigator	:	A P Manyike, School of Health Systems and Public Health, University of Pretoria (SUPERVISORS:Dr N Claassen / Prof B Girdler-Brown)
Sponsor	:	None
Study Degree:		**MPH**

This Student Protocol was reviewed by the Faculty of Health Sciences, Student Research Ethics Committee, University of Pretoria on 17/10/2012 and found to be acceptable. The approval is valid for a period of 3 years.

Prof M J Bester	BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc (Biochemistry); PhD (Medical Biochemistry)
Prof R Delport	(female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education
Dr NK Likibi	MBB HM – (Representing Gauteng Department of Health) MPH
Dr MP Mathebula	Deputy CEO: Steve Biko Academic Hospital
Prof A Nienaber	(Female) BA (Hons) (Wits); LLB (Pretoria); LLM (Pretoria); LLD (Pretoria); PhD; Diploma in Datametrics (UNISA)
Prof L M Ntlhe	MBChB(Natal); FCS(SA)
Mrs M C Nzeku	(Female) BSc(NUL); MSc Biochem(UCL,UK)
Snr Sr J. Phatoli	(Female) BCur (Et.Al); BTech Oncology
Dr R Reynders	MBChB (Pret), FCPaed (CMSA) MRCPCH (Lon) Cert Med. Onc (CMSA)
Dr T Rossouw	(Female) MBChB.(cum laude); M.Phil (Applied Ethics) (cum laude), MPH (Biostatistics and Epidemiology (cum laude), D.Phil
Mr Y Sikweyiya	MPH (Umea University Umea, Sweden); Master Level Fellowship (Research Ethics) (Pretoria and UKZN); Post Grad. Diploma in Health Promotion (Unitra); BSc in Health Promotion (Unitra)
Dr L Schoeman	(Female) BPharm (NWU); BAHons (Psychology)(UP); PhD (UKZN); International Diploma in Research Ethics (UCT)
Dr R Sommers	**Vice-Chair** (Female) - MBChB; MMed (Int); MPharMed.
Prof T J P Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE
Prof C W van Staden	**Chairperson** - MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM; Dept of Psychiatry

Student Ethics Sub-Committee

Prof R S K Apatu	MBChB (Legon,UG); PhD (Cantab); PGDip International Research Ethics (UCT)
Mrs N Briers	(female) BSc (Stell); BSc Hons (Pretoria); MSc (Pretoria); DHETP (Pretoria)
Prof M M Ehlers	(female) BSc (Agric) Microbiology (Pret); BSc (Agric) Hons Microbiology (Pret); MSc (Agric) Microbiology (Pret); PhD Microbiology (Pret); Post Doctoral Fellow (Pret)
Dr R Leech	(female) B.Art et Scien; BA Cur; BA (Hons); M (ECI); PhD Nursing Science
Mr S B Masombuka	BA (Communication Science) UNISA; Certificate in Health Research Ethics Course (B compliant cc)
Dr S A S Olorunju	BSc (Hons). Stats (Ahmadu Bello University –Nigeria); MSc (Applied Statistics (UKC United Kingdom); PhD (Ahmadu Bello University – Nigeria)
Dr L Schoeman	CHAIRPERSON: (female) BPharm (North West); BAHons (Psychology)(Pretoria); PhD (KwaZulu-Natal); International Diploma in Research Ethics (UCT)
Dr R Sommers	**Vice-Chair** (Female) MBChB; M.Med (Int); MPhar.Med
Prof L Sykes	(female) BSc, BDS, MDent (Pros)

DR L SCHOEMAN; BPharm, BA Hons (Psy), PhD;
Dip. International Research Ethics
CHAIRPERSON of the Faculty of Health Sciences
Student Research Ethics Committee, University of Pretoria

DR R SOMMERS; MBChB; M.Med (Int); MPhar.Med.
VICE-CHAIR of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

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Addendum A5: Application for a research topic change & Response from the APC

120 Voortrekker street

Lydenburg

1120

University of Pretoria

School of Public Health Systems

The Chairperson: APC Committee

Application for a research topic change: ***A Descriptive Study to Determine the Prevalence of Chronic Obstructive Airways Disease amongst Load Haul Drivers (LHD) in Trackless Mines***

With reference to the scientific research protocol that I submitted to the school Ethics committee during November 2012, I hereby apply for the change in my research topic to a new topic which is as follows: ***A Descriptive Study to Determine the Prevalence of Obstructive Airway Disease amongst Load Haul Drivers (LHD) in Trackless Mines***

I am currently compiling a final report for the study I conducted under the specified research topic above. During the analysis stage of the results I reviewed several latest research articles related to chronic Obstructive Airway Disease (COPD), and noted that there has been new respiratory questionnaire /templates developed which are now recommended for use when assessing and classify Chronic Obstructive Airway Disease. As a result, I would not be able to report the prevalences of COPD as initially planned since the type of questionnaire that I have used differs from the ones recommended for use. However, I have collected enough data that will allow me to report on the prevalence of obstructed airway disease without classifying it into COPD using GOLD classification methodology. I will report purely on the ratio of FEV1/FVC conducted on the participants without the use of bronchodilator.

I believe that the study results will still have an impact on the importance of using a risk based medical surveillance for the LHD drivers in the mine in order to prevent deterioration of their health. I also believe that the study will form a basis for further studies using the correct questionnaire and GOLD classification to further improve the health of the LHD drivers.

I therefore request that the committee take my application into consideration and grant me a permission to change the research topic as stated above.

Yours Faithfully

Amukelani Portia Manyike

Student Number: 10550969

01 May 2014.

FACULTY OF HEALTH SCIENCES

School of Health Systems and Public Health

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

Academic Programme Committee Meeting

Minutes, 9 May 2014 at 09:30

16. General	**16.6 Manyike AP – 10550969 (MPH) - Change of Topic title – Girdler-Brown. Approved.** **New title must be entered on SHSPH database.**	**SH, LW,** **FS: 2014**		