DETERMINANTS OF FUNCTIONAL CAPACITY AND WORK ABILITY POST SARS-COV-2 INFECTION IN MINERS

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NDLVUS004

A research report submitted to the School of Public Health, University of Cape Town in partial fulfilment of the requirement for the award of the degree of Master of Philosophy (MPhil) in Occupational Health

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- 28 JANUARY 2025 -

PLAGARISM STATEMENT

I, Vusimuzi Ndlovu, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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DEDICATION

To my wife Sine, iThembalam, thank you for always being the wind beneath my wings.

May this degree inspire you too to dream bigger about your own career.

To our children Uya, Okuhle, Nalani, I hope my journey will forever remind you not to let your circumstances define you.

To oNdlovu oSgomelo who are no longer in this world but continue to walk with me and light my path, I am forever indebted to you.

ACKNOWLEDGEMENTS

I wish to express my most sincere gratitude to my supervisors from the Occupational Medicine Division in the School of Public Health, University of Cape Town. Thank you for your role in educating students to become world class professionals:

- Prof. Mohamed Jeebhay
- Dr. Itumeleng Ntatamala

I wish to thank Dr Roslynn Baatjies in the Occupational Medicine Division for her assistance with navigating the STATA software and guiding me through my data analysis.

Furthermore, I wish to thank the various administrators in the Occupational Medicine Division for assistance with administrative issues:

- Faranaaz Bennet
- Liza Smith
- Bulelwa Manxiwa
- Lynne Harper

Finally, I would like to thank the Foundation for Human Rights in South Africa for the financial assistance provided to fund my academic studies in pursuit of this degree. Your support has enabled an important study to be conducted among the miners in the Northern Cape.

ABSTRACT

Background

Insufficient data exists on the sequelae of COVID-19 and its impact on function and work ability among workers. The aim of this study was to investigate the determinants of functional capacity and work ability in miners following COVID-19 disease.

Methods

This cross-sectional study recruited 204 mine workers employed at a ferromanganese mine in the Northern Cape province of South Africa with a confirmed laboratory diagnosis of COVID-19 within the past 12 months. Study instruments included a socio-demographic questionnaire, Post COVID-19 Functional Scale (PCFS), Work Ability Index (WAI), chest radiograph and the Two-minute Walk Test (TMWT). Data analysis was done using STATA version 16 to generate univariate and multivariate quantile regression models.

Results

The majority (74%) of the participants were males with a mean age of 38.8 years and employed in the mining department (46%) as operators. A third were current smokers (35%), and obese (36%). The most commonly reported acute COVID-19 symptoms were sore throat (56%), cough (43%), and anosmia (34%). Almost all the participants had reported having two or more episodes of COVID-19 which was of a mild form (64%). Most (86%) returned to work within 14 days of diagnosis. None of the miners had an abnormal PCFS score, nor did they have poor WAI scores. Aside from living arrangements (living with a spouse), none of the socio-demographic or occupational factors were associated with COVID-19 disease severity. Unlike for COVID-19 disease, female sex was significantly associated ($p<0.001$) with poor performance on the TMWT in the simple regression models. After adjusting for disease severity and sex in the multivariate models, no significant association was observed between COVID-19 disease and the TMWT distance.

Conclusion

This study found limited evidence of impaired functional capacity and work ability in miners following COVID-19 disease within one year of SARS-CoV-2 infection. Furthermore, only female sex, but not COVID-19 was associated with impaired functional ability.

Keywords Miners, post COVID-19 syndrome, functional capacity, work ability.

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

AIDS:	Acquired immunodeficiency syndrome
COPD:	Chronic obstructive pulmonary disease
COVID-19	Coronavirus Disease 2019
CPET	Cardiopulmonary exercise test
CT	Computed Tomography
CXR:	Chest x-ray
D_{LCO}:	Diffusion capacity of lung for carbon monoxide
FEV_1:	Forced expiratory volume in 1 second
FVC:	Forced vital capacity
HIV:	Human immunodeficiency virus
ICU:	Intensive care unit
MERS	Middle east respiratory syndrome
MPHIL:	Master of philosophy
LMIC	Low-to-middle-income country
6MWT:	6-minute walk test
OMP	Occupational Medical Practitioner
OHNP	Occupational Health Nursing Practitioner
PCFS:	Post COVID-19 functional status
PCR:	Polymerase chain reaction
PFT:	Pulmonary function test
RFA:	Rehabilitation and functional assessment
SARS-COV-2:	Severe acute respiratory syndrome corona virus 2
TB:	Tuberculosis
TMWT:	Two-minute walk test
$V'_{O2\ PEAK}$:	Peak oxygen uptake

LIST OF TABLES AND FIGURES

JOURNAL MANUSCRIPT

DETERMINANTS OF FUNCTIONAL CAPACITY AND WORK ABILITY POST SARS-COV-2 INFECTION IN MINERS

INTRODUCTION

On the 11th of March 2020, the World Health Organisation (WHO) declared COVID-19 as a global pandemic. Since then over 700 million people have been infected worldwide with over 7 million deaths despite increasing efforts of providing COVID-19 vaccines[1]. In South Africa, reported COVID -19 cases reached 4 076 463 by April 2024 with reported deaths being 102 595[2].

SARS-CoV-2 infection has been associated with both acute and chronic health effects, including the post COVID-19 syndrome. Post COVID-19 syndrome (PCS) is defined by the WHO in terms of probability based on a positive history; confirmatory laboratory diagnosis of SARS-CoV-2 infection; onset of symptoms 3 months after acute COVID-19 lasting over two months duration, in the absence of an alternative diagnosis[3]. While studies to better understand the natural history and long-term health effects of COVID-19 continue, many studies have shown that the syndrome is mainly characterised by persistent fatigue, cognitive dysfunction and respiratory impairment[4]. PCS appears to affect survivors who had the severe form of the disease. Perez-Gonzalez et al[5] further reported that PCS symptoms are significantly more common in hospitalized compared to non-hospitalized patients (52.3% vs 38.2%). Some studies have estimated the incidence of PCS to be 50% -70% in hospitalised cases[7,11,12]. Other important risk factors associated with PCS include the presence of pre-existing illness (cardiorespiratory, autoimmune, oncological and neuropsychiatric disorders), female sex, respiratory symptoms at onset and length of hospital stay[6]. In these studies, patients reported limitations in their ability to work, even in sedentary occupations where physical fitness has little or no impact on work ability[6,7,11,12].

Specific working populations or occupations have been associated with increased risk of COVID-19, including frontline healthcare workers, essential workers including those in the retail industry, energy sectors and mining[7]. In South Africa, the mining industry response to the COVID-19 pandemic was guided by the Department of Minerals and Energy's mandatory guidelines and code of practice on the mitigation and management of the COVID-19 outbreak[8]. Risk mitigation measures included compulsory temperature screenings at entry points, testing of symptomatic individuals, contact tracing, isolations, quarantines and vaccination. It is reported that by July 2022, 66 113 miners were infected (incidence rate 15%, with over 750 having died (death rate 1.7%) due to the pandemic[8]. Risk factors reported in miners included migration in the early parts of the pandemic, inadequate control measures, poor ventilation in mine shafts, overcrowded living areas, transportation to work, and the double burden of silico-tuberculosis and HIV[9]. The impact of PCS on the working populations in high income industrialised countries is well documented. Aiyegbusi et al[10] established that the impairment experienced by COVID-19 survivors with PCS were likely to be associated with decreased functioning in daily life, quality of life, and employment. Furthermore, it has been documented that the majority of persons with PCS were in the economically active subgroup of the population, having a mean age of 40 years[11].

While PCS is widely studied across the general population of first world countries, there is a paucity of data in the South African mining context, particularly in the open cast ferromanganese sector regarding long term effects associated with COVID-19. In South Africa, there are over 500 mines registered with the Department of Minerals and Energy (DMRE) and contributing to the Gross Domestic Product (GDP) and employment. The largely migrant workforce in this sector is at risk of developing occupational respiratory diseases such as tuberculosis, silicosis and chronic obstructive lung disease. Naidoo and Jeebhay[9] argued that this could potentially increase the vulnerability of South African miners to COVID-19 infection and further impact on work ability. PCS is therefore a concern in mining and construction in particular where high levels of physical fitness are a required. This study aimed to establish the determinants of functional capacity and work ability and the extent to which persistent symptoms post COVID-19 impacted on functional capacity and work ability in open cast miners in the Northern Cape province of South Africa.

METHODS

Study design

This was a cross-sectional study of adult mine workers (>/=18 years of age) working in a ferromanganese mine in the Northern Cape province of South Africa who had been infected with SARS-CoV-2 (diagnosed on PCR) since the onset of the pandemic in 2020. The study was conducted from January to August 2023.The study was approved by the Human Research Ethics Committee of the University of Cape Town (HREC303/2022) and consent to conduct research on the mine premises was granted by the mine management (**Appendix 1**). Informed and signed consent (**Appendix 2**) was obtained from each participant prior to their enrolment into the study. Participation was voluntary and workers could withdraw at any time.

Population

The ferromanganese mine employed approximately 5000 employees including contractors (70%). By the 30th of April 2022, a total of 1663 employees (permanent employees and contractors) had tested positive since the start of the COVID-19 pandemic, while 733 cases from the total positive pool had been diagnosed in 2021. The mine established a COVID-19 Hub in the occupational health department in March 2020 to manage all aspects of COVID -19 including testing, contact tracing, post isolation, fitness assessment and management of complications for all employees including contractors and onsite senior management.

Sampling method

Participants were identified through the mine COVID-19 lists as well as those visiting the mine occupational health clinic to undergo medical surveillance. The selection of participants was based on the time since the onset of symptoms of COVID-19. The inclusion criterion was a positive SARS-CoV-2 PCR test present in the past 12 months from the date of recruitment. Only employees aged 18 years and above who were manual labourers were recruited. Employees in sedentary occupations such as office jobs were excluded.

Data collection

1. ***Subjective health assessment and work ability***

A questionnaire containing sociodemographic and medical characteristics, the Post COVID-19 Functional Status Scale (PCFS), and the Work Ability Index (WAI) was completed via a structured interview. The components were administered by an Occupational Medical Practitioner in English and translated for the participants who were not conversant in English . The time allocated for each interview was approximately 40 minutes.

1.1 Sociodemographic Questionnaire

Each participant was asked socio-demographic questions (**Appendix 3**) including age, sex, marital status, education level, living circumstances; occupational details (occupation, department, length of service), habits (smoking, exercise frequency, substance abuse); and their medical history (previous TB, silicosis, asthma, COVID-19 details, HIV, hypertension, diabetes diagnosis).

1.2. Post COVID-19 Functional Status scale (PCFS).

The Post COVID-19 Functional Status scale (PCFS) is a tool developed specifically to measure the functional status of patients after an infection with COVID-19 (**Appendix 4**). The scale is graded from zero to four where grade zero represents no functional limitation and grade four equates to severe functional limitation. The PCFS questionnaire was administered through a structured interview using a series of questions structured in the flow chart format. Participants were instructed to consider their functional status in the previous week.

The advantage of the PCFS is its translatability and ability to be adapted across different cultures. The scale has also been shown to be reliable and demonstrates internal consistency, and convergent validity in studies evaluating its measurement properties[12].

The PCFS scores were graded on a scale 0 to 4, where Grade 0 is no functional limitations, Grade 1 represents negligible functional limitations (can perform normal daily activities including sports). A Grading of 2 equates to negligible functional limitations while Grades 3 and 4 means the respondent had moderate and severe functional limitation respectively. A Grade 4 PCFS meant the respondent needed assistance with routine activities of daily living (ADLs) such as hygiene and mobility.

1.3. Work Ability Index (WAI)

The WAI (**Appendix 5**) is a validated tool that has been used in occupational health research to assess work ability during workplace surveys [13]. It has been shown to be effective in predicting work disability, retirement and mortality and has been used widely in studies from different countries and translated into 24 languages. Its validity and reliability have been assessed and have been found to be reliable in predicting work disability, retirement and mortality.

The WAI covered 7 aspects related to current occupation and abilities post recovery from a medical condition. In this case, the condition of interest is SARS-CoV-2 infection. The questions prompted the subject to respond based on a grade on a given number scale. The questions covered work ability, comorbidities, impairment, sick leave, prognosis and mental resources.

The sum total of the score was then used to grade workability from poor to excellent, in which the lowest score represented poor work ability and the highest score excellent work ability. The grading was as follows: Poor (7-27); Moderate (28-36); Good (37-43) and Excellent (44-49). The grading system further gives recommendations on appropriate corrective actions.

2. *Objective health assessment and functional ability* (Appendix 6)

2.1 Anthropometric assessment

The participants height and weight were measured and recorded in order to calculate the Body Mass Index BMI (using the formula: BMI = height/(height)^2).

2.2 Chest radiograph

Since yearly chest radiographs are mandatory for miners, the participants' latest pre-COVID chest radiograph was compared to a single chest radiograph within 12 months post-COVID-19. Posterior-anterior views of participants were taken and analysed by an experienced Occupational Medical Practitioner for new changes when compared with the pre-COVID-19 radiographs using a standardized form (**Appendix 7**).

2.3 Exercise Tolerance - Two Minute Walk Test (TMWT).

The Two Minute Walk Test (TMWT) (**Appendix 8**) is a suitable test for functional endurance that has been validated in a variety of settings. Bohanon et al[14] were able to demonstrate its reliability and responsiveness in a meta-analysis study in 2017. They looked at four studies and produced normative values based on those studies. Butland et al[15] in 1982 and Connelly et al[16] 27 years later showed that the 2MWT performance measurements are reliable and correlated with subject performances on the 6MWT.

In the TMWT, the participant was asked to walk and cover as much ground as possible in a timed period of 2 minutes. The same circuit was used for all participants. The distance covered was measured using a measuring wheel. Before and post the walk test, oxygen levels were recorded.

The criteria for discontinuing the test included: abnormal pre-TMWT oxygen saturation levels <90%; chest pain which does not resolve at rest, dyspnoea precluding continuation of walking, contractures of lower limb muscles, balance disorders, severe sweating, pallor or cyanosis. Participants in the TMWT were monitored by an experienced Occupational Medical Practitioner throughout. Resuscitation readiness was ensured to enable a timeous response in case of complications during the test.

Data management

The key outcome variables included the presence of symptoms at any stage post-COVID-19, functional limitation as assessed by the PCFS with grading above 0, and abnormal scores on both the TMWT and WAI. Abnormal chest radiographs were classified based on the comparison with the latest Pre-COVID-19 radiograph to determine the presence of new changes associated with COVID-19. The independent variables included the age of the participant, BMI, sex, number of episodes of SARS-CoV-2 infection, the severity of acute SARS-CoV-2 infection and comorbidities present. Data collected through the questionnaires was stored in a password-protected excel spreadsheet. Results of the clinical assessment were stored in the same format on a password-protected computer.

Data Analysis

Statistical analysis was done through the STATA 16 program (StataCorp, College Station, Texas, USA) obtained through the University of Cape Town. Counts (n) and proportions (%), means with standard deviations and medians with interquartile range (IQR) were used to present descriptive statistics depending on the type and distribution of data. To investigate associations, univariate and multivariate quantile regression models were computed and presented as β-coefficients with 95% confidence intervals (CI). The multivariate quantile regression models controlled for age, sex, BMI, social status, smoking status, cigarettes per day, alcohol use, occupation and chronic disease.

RESULTS

Population and demographic characteristics of miners

The sociodemographic characteristics on the miners are presented in **Table 1.** The study included 204 working miners employed at the ferromanganese mine in the Northern Cape Province of South Africa. The population was mostly male (74%) and the majority (41%) were between the ages 30 - 39 (Mean age: 39, IQR, 20-69). Less than half of the subjects had attained a tertiary education (42%). A larger portion of the respondents indicated that they lived with their spouses (69%). Recreational substance usage was present, with daily tobacco/cigarettes (35%) and alcohol (47%) being the substances most commonly used.

The prevalence of chronic disease among the participants was 20% (n=41), with hypertension (44%) and obesity (36%) being the most commonly self-reported chronic diseases, while diabetes (20%) and HIV (17%) were the less commonly reported diseases. Some participants reported more than one chronic illness, 3% had more than one comorbidity.

Table 1. Socio-demographic characteristics of miners (n=204)

Participant characteristics		**Frequency (n = 204)**	**%**
Age, years	20 -29	28	14
	30-39	84	41
	40-49	69	34
	50-59	19	9
	60-69	4	2
Sex	Male	152	74
	Female	52	25
Social status	Lives alone	63	31
	Lives with spouse	141	69
Education	Primary (Grade R -7)	47	23
	Secondary (Grade 8 -12)	71	35
	Tertiary	85	42
Smoking	Smoker	72	35
	Non-smoker	62	30
	Ex-smoker	70	34
Cigarettes/day	1-9	16	26
	10-19	33	53
	20-29	12	19
	>/=30	1	2
Alcohol use	Current alcohol consumption	95	47
	Non-drinker	65	32
	Ex-drinker	44	22
Alcohol drinks/day	1 unit	62	65
	> 1 unit	33	35
Chronic disease	Yes	41	20
Chronic disease conditions (n= 41)	Hypertension	18	44
	Diabetes	8	20
	HIV/AIDS	7	17
	Asthma	2	5
	*Other	8	20
BMI Categories (kg/m^2)	Underweight (<18.5)	6	3
	Normal (18.5-24.9)	70	34
	Overweight (25 -29.9)	54	26
	Obese (>30)	74	36

*Participants may have more than one condition. *Other conditions included Gout, COPD, Mental illness.

Occupational characteristics of miners

The occupational characteristics are tabulated in **Table 2** below. Most worked in the mining department (46%) while a quarter (26%) were operators (drivers of large earth moving machinery). Most (66%) worked 12-hour shifts. The majority of the participants worked overtime (52%) with 11-20 hrs being the most commonly worked hours.

Table 2. Occupational characteristics of miners (n=204)

Participant characteristics		**Frequency (n = 204)**	**%**
Occupation	Operator	54	26
	Artisan	25	12
	General worker	24	12
	Supervisor	24	12
	Learnership/Interns	13	6
	Artisan Assistant	11	5
	Technician	11	5
	Safety Officer		4
	Professional	9	4
	Construction Worker	8	4
	Driver	5	2
Department	Mining	93	46
	Plant	43	21
	Engineering	33	17
	SHEPS*	25	12
	Workshop	10	5
Work schedule	Straight shift (06h00 -16h00)	69	34
	Shifts (06h00 – 18h00)/12 hrs	135	66
Overtime	Yes	10	52
Overtime hrs per week	0-10	47	44
	11-20	53	50
	21-30	5	5
	31-40	2	2

*SHEPS: Safety, Health, Environmental Protection Services

COVID-19 related characteristics of miners

All 204 participants had been diagnosed with COVID-19 after January 2022 using PCR testing. The symptoms reported by subjects in the acute phase COVID-19 infection is shown in **Table 3**. The most commonly reported symptoms were sore throat (56%), cough (43%), anosmia (34%), headache (30%), ageusia (25%), and runny nose (23%). The majority of the participants (91%) reported having more than one symptom at the time of diagnosis.

Table 3. Prevalence of general COVID-19-related symptoms in miners (n=204)

Symptoms*	**Frequency (n = 204)**	**%**
Sore throat	115	56
Cough	88	43
Anosmia	69	34
Headache	61	30
Ageusia	50	25
Runny nose	47	23
Body pain	43	21
Mental fog	42	21
Diarrhoea	42	21
Dizziness	35	17
Fatigue	33	16

*Participants may have reported >1 symptom

Table 4 illustrates a breakdown of various aspects relating to COVID-19 in our study population. The majority of participants (62%) had their first COVID-19 infection in 2021. Similarly, a large proportion (62%) reported at least 2 episodes of COVID-19 from the start of the pandemic in 2019, while 31% reported 3 COVID-19 episodes and much fewer (5%) reported 4 episodes. Regarding COVID-19 severity, 64% reported having only mild symptoms, 23% had moderate severity disease while 14% had severe disease requiring hospital admission. Most participants (92%) had at the time of recruitment received at least 1 dose of the COVID-19 vaccine (Pfizer and Johnson and Johnson). The majority of participants were able to return to work within 14 days of diagnosis (86%). Those subjects (15%) with working days lost due to COVID-19 illness reported reasons for the delay in returning to work as being due to admission into a hospital ward (10%), ICU admission (4%) and a small proportion receiving rehabilitation (1%).

Table 4. COVID-19-related characteristics of miners (n=204)

Participant characteristics		**Frequency (n = 204)**	**%**
Infection in the past year		204	100
COVID-19 episodes ever	1	3	1
	2	127	62
	3	64	3
	4	10	15
Date of 1st infection (year)	2020	62	31
	2021	122	62
	2022	8	4
	Unknown	12	3
Severity	Mild	130	64
	Moderate/>3 symptoms	46	23
	Severe/hospitalized	28	14
Mode of diagnosis	PCR	204	100
Vaccination status	Vaccinated	188	92
	Unvaccinated	16	8
Days absent due to COVID-19	10-14 days	175	86
	14 -28 days	26	13
	>1 month	3	1
Delayed RTW	Yes	31	15
Reasons for delayed RTW	Ward admission	20	10
	ICU admission	9	4
	Rehab	2	1

RTW: Return to work, ICU: Intensive Care Unit, PCR: Polymerase Chain Reaction.

Lung disease in miners

The pre-employment or periodic x-rays done as part of medical surveillance were analysed using the International Labour Organisation (ILO) classification to determine if fibrotic or other changes were present post COVID-19 infection. Comparison of pre- and post COVID-19 chest x-rays showed that only 2 of the 204 participants (1%) had evidence of post PTB parenchymal changes and none had radiological features of silicosis or post-COVID-19 fibrosis.

Impairment and disability outcomes in miners

Two-Minute-Walk-Test (TMWT)

None of the participants had oxygen saturation levels less than 90% pre and post the TMWT. On pre-test assessments, half of the participants (52%) had levels greater or equal to 95% while the remainder (48%) had levels between 90% and 94%. Post the TMWT, 53% had levels in the range 90%-94% while the rest (47%) remained at levels ≥ 95%.

Consolidated values from four studies compiled by Bohannon[14] , were used as predictor values or comparisons for the TMWT distances achieved by the participants in the study. The results of the TMWT are presented in **Table 5**. The males (stratified by age) did comparatively better than the predicted values while the females walked shorter distances ($p < 0.05$ for different age groups). The exception to this was the group male 20-29 years whose mean distance was 214.13m compared to the predicted mean of 217.9m ($p=0.158$).

Table 5. Two-minute walk distance in miners stratified by age and sex (n=200)

Age (yrs), Sex (n)	Frequency (n=200)	%	Mean distance(m) (SD)	Predicted reference values# (m) (Mean, SD)	p-value*
Men 20-29 yrs.	19	10	214.13 (11.14)	217.9 (5.4)	0.158
Women 20-29 yrs.	8	4	165.5 (14.76)	194.1 (8.4)	0.001
Men 30-39 yrs.	59	30	214.13 (8.49)	202.1 (3.0)	<0.001
Women 30-39 yrs.	22	11	171.68 (13.57)	181.4 (1.7)	0.003
Men 40-49 yrs.	51	26	209.35 (28.08)	192.1 (2.7)	<0.001
Women 40-49 yrs.	18	9	171.59 (17.59)	180.7 (10.4)	0.042
Men 50-59 yrs.	17	9	212.57 (7.23)	189.8 (2.6)	<0.001
Women 50-59 yrs.	2	1	157.05 (9.12)	169.1 (10.6)	0.313
Men 60-69 yrs.	2	1	216.45 (4.45)	183.0 (7.0)	0.060
Women 60-69 yrs.	2	1	168.17 (10.65)	163.7 (6.9)	0.659

* One sample t-test, # Reference values of Bohannon R.W. (2017)

The results of the PCFS and WAI are shown in **Table 6** below.

Post COVID-19 Functional Status Scale (PCFS)

The majority of participants (96%) had a Grade 0 PCFS grading, indicating no functional limitation while 4% had Grade 1, indicative of negligible limitation. No participants had scores in the Grade 2 to Grade 4 categories, indicating that there was no mild to severe functional impairment reported in miners.

Work Ability Index (WAI)

Most participants (86%) had WAI scores within the 37 - 43 range indicating standard work ability rating category of '*Good'*. Fewer (11%) scored in the excellent range (40-49), while 2% scored in the moderate range (28-36). There were no employees that scored less than 28 (scores in the 7-27 range are indicative of poor work ability).

Table 6. Impairment and disability outcomes in miners (n=204)

	Total WAI score	Frequency, %	%
PCFS grading	Grade 0	195	96
	Grade 1	9	4
	Grade 2-4	-	
WAI Total score	7 – 27 - Poor	0	0
	28 – 36 - Moderate	5	2
	37 – 43 - Good	176	86
	44 – 49 - Excellent	23	11

PCFS: Post COVID-19 Functional Scale, WAI: Work ability index

Socio-demographic and occupational characteristics associated with severity of COVID-19 disease.

Table 7 illustrates the socio-demographic and occupational characteristics of the participants stratified by severity of the COVID-19 disease (mild vs moderate/severe). The study did not show any significant association between socio-demographic and occupational factors with disease severity (p >0.05), except for social status.

Table 7. Socio-demographic and occupational characteristics in miners stratified by severity of COVID-19 disease.

Characteristic	Total (n)	Mild (n=130)	%	Moderate / Severe (n=74), (%)	%	p-value
Socio-demographic						
Age, years (mean, SD)	204	38.35	0.75	39.65	1.06	0.311
Sex						
- Female	52	36	69	16	31	0.339
- Male	152	94	62	58	38	
BMI						
- Normal (<24.9 kg/m^2)	76	47	62	29	38	0.666
- Overweight/Obese (≥25 kg/m^2)	128	83	65	45	35	
Education						
- Primary/secondary	119	78	66	41	34	0.522
- Tertiary	85	52	61	33	39	
Social status						
- Lives alone	63	47	75	16	25	**0.031**
- Lives with spouse	141	83	59	58	41	
Smoking						
- Smoker*	142	93	65	49	35	0.427
- Non-smoker	62	37	60	25	40	
Cigarettes /day						
- <10/day	40	21	53	19	48	0.100
- ≥10/day	164	109	66	55	34	
Alcohol use						
- Drinker#	109	70	64	39	36	0.875
- Non-drinker	95	60	63	35	37	
Drinks/day						
- 1unit/day	33	19	58	14	42	0.411
- >1 unit/day	62	41	66	21	34	
Chronic disease						
- Yes	41	27	66	14	34	0.751
- No	163	103	63	60	37	

* Smoker/ex-smoker data combined, # Drinker/ex-drinker data combined
** Chi-square (except for age)

Table 7 continued. Socio-demographic and occupational characteristics in miners stratified by severity of COVID-19 disease.

Characteristic	Total (n)	Mild (n=130)	%	Moderate / Severe (n=74)	%	p-value
Department						
- Surface	111	68	61	43	39	0.424
- Pit	93	62	67	31	33	
Work schedule						
- Straight shift (06h00-16h00)	69	42	61	27	39	0.544
- Shifts (12hr cycle)	135	88	65	47	35	
Overtime/week						
- 0-10 hrs.	47	27	57	20	43	0.307
- 11-40 hrs.	157	103	66	54	34	

* Smoker/ex- smoker data combined, # Drinker/ex-drinker data combined

** Chi-square (except for age)

Determinants of TMWT distance in miners post COVID-19 diagnosis

Quantile regression models for determinants of TMWT distance in miners post COVID-19 diagnosis are presented in **Table 8**. In the simple regression analysis, only sex was a statistically significant determinant of distance walked on the TMWT, with females walking shorter distances their male counterparts (Beta coefficient= -43.95, 95% CI: -48.71 to -39.19, p<0.001). Furthermore, the multivariate regression analysis did not identify any significant patterns or relationships.

Table 8: Quantile regression models for determinants of TMWT distance in miners post COVID-19 diagnosis.

Univariate analysis	β-coefficient	95% CI	p-value
Socio-demographic			
Age	-0.02	-0.315 to 0.312	0.992
Sex (female)	-43.95	-48.71 to -39.19	<0.001
BMI	-0.13	-0.61 to 0.34	0.583
Social status	-1.30	-7.65 to 5.05	0.687
Smoking Status	-0.030	-5.48 to 5.54	0.991
Cigarettes per day	-0.90	-7.83 to 6.03	0.798
Alcohol use	4.20	-1.21 to 9.61	0.127
Drinks per day	-5.00	-17.03 to 7.03	0.413
Occupational			
Department	-0.03	-5.39 to 5.33	0.991
Shift work	5.00	-1.32 to 11.32	0.120
Overtime hours worked	4.60	-2.99 to 12.19	0.233
Medical			
COVID-19 severity	1.30	-4.53 to 7.13	0.660
Chronic disease	3.70	-2.87 to 10.27	0.268
Multivariate models for COVID-19 severity as key predictor of TMWT distance			
COVID-19 severity + sex	-2.60	-6.72 to 1.52	0.215
COVID-19 severity + (sex, age, BMI, smoking)	-2.67	-6.97 to 1.62	0.222
COVID-19 severity + (sex, age, BMI, smoking, asthma)	-2.67	-7.00 to 1.66	0.225

TMWT: Two-minute Walk test, BMI: Body mass index, CI: Confidence Interval

DISCUSSION

In this study of relatively young, mostly male miners, there was limited evidence of impaired functional capacity and work ability in miners following COVID-19 disease within one year of SARS-CoV-2 infection. Furthermore, only female sex, but not COVID-19 disease severity, was associated with impaired functional ability as determined by the TMWT. This was probably related to the relatively young, and generally fit miners, who had the mainly mild form of the infection and good access to health care.

The study found that the majority of participants had a mild form of COVID-19 disease with 64% having less than 3 symptoms. The most common symptoms reported were referable to the respiratory tract, being sore throat (56%), cough (43%) and anosmia (34%). Dryden et al[17] in their study conducted in the South African population also found that just over half (51.7%) of participants reported four or more acute COVID-19 related symptoms. In their study, the commonly reported symptoms were fatigue/malaise (57%), shortness of breath (48.8%) and fever (44.8%). The differences in the prevalence of the most commonly reported symptoms may be due to several differences between the two studies. Dryden et al[17] interviewed SARS-CoV-2 infected patients within one month of infection whereas, in the current study, interviews were conducted up to 12 months since infection, when most symptoms would have receded in those that were mildly infected as was evident in this group of miners. Furthermore, unlike other studies [17,18,19], our study did not investigate persistent symptoms at various time intervals to determine the presence and prevalence of PCS.

A large proportion (62%) of the miners in this current study had been infected on at least two occasions. In a systematic review and metanalysis Gorbhani et al[18] found that the pooled estimation of re-infection rate among recovered COVID-19 patients was 3 per 1000 patients while the pooled estimation of recurrence rate among recovered COVID-19 patients was 133 per 1000 patients. By 2022 when the current study data was collected, many more variants of the SARS-CoV-2 virus had emerged increasing the likelihood of re-infection. Interestingly, an increasing frequency of re-infection with SARS-CoV-2 was not associated with greater functional impairment and disability in our study, which is similar to the findings of Fabiánová et al[19] in the Czech Republic. The study, which was done during the peak of the pandemic in 2020, showed that the rate of symptomatic reinfection with the SARS-CoV-2 virus was 0.2% and higher (0.5%) if asymptomatic patients were included. The sharp contrast between these two studies may be attributed to subjects having mild symptoms in the second episode leading to underdiagnosis in the Czech study compared to the vigilant testing protocols for SA mines that required PCR testing even for miners with mild symptoms.

In the current study, no association between socio-demographic and occupational risk factors and severity of the disease was found. This is in contrast to many other studies, which consistently reported that poor metabolic health and chronic disease (obesity, type 2 diabetes or hypertension) was associated with increased risk and severity of COVID-19 [20,21,22]. One South African study also reported higher mortality from COVID-19 in patients with HIV or TB[23]. Other risk factors for COVID-19 reported in the literature include older age (>65), male sex and obesity. Despite the current study having 2% of subjects between the ages 60-69 years, 74% being males and 36% with BMI >30 kg/m^2, the incidence of severe disease was surprisingly low compared to other studies[24]. This is likely due to early diagnoses, referral and treatment in the context of miners with better access to health care on the mines. While 41% of study subjects in the current study reported having comorbid illness only 37% had experienced a moderate to severe form of COVID-19 disease and only 14% requiring hospital admission including ICU. However, larger studies such as Dryden et al[17], found a high prevalence of comorbidities and larger proportions of individuals being admitted to hospital (34%) and ICU (28%). Overall, the better outcomes in the current study could be due to their pre-existing level of fitness present in miners as a result of the arduous nature of work and the stringent COVID -19 management measures implemented by the mining industry in South Africa [25] and can also be explained by the healthy worker effect. Such measures included daily screenings, contact tracing, early referral to hospitals which meant that infected miners received timeous treatment in the early stages of the disease and progression was minimised.

A noteworthy association observed in the current study was the link between living with a spouse and having a severe form of COVID-19 disease. Various studies have reported that a wide range of social factors, including socioeconomic status, racial/ethnic minority status, family or household composition, and environmental factors, were significantly associated with

COVID-19 disease incidence and mortality[26]. A possible explanation for this finding could be that exposure to a greater likelihood of more inhabitants infected with the virus in these households compared to those living on their own as has been demonstrated in other studies[27].

The prevalence of abnormal radiological findings in the current study was very low (1%). This was not surprising given the age range of the participants. Furthermore, none of the participating miners had any changes suggestive of pneumoconiosis commonly found in miners nor evidence of COVID-19 disease. Studies have shown that even in the acute stages of COVID-19 disease, a large proportion (> 85%) of patients who test positive have negative chest x-ray findings[28]. In the minority of patients with chest x-ray abnormalities Rousan et al[28] have reported that the most common finding in patients was ground glass opacities in a peripheral distribution with bilateral lung involvement. They further noted that almost half the patients with COVID-19 disease had abnormal chest x-rays and that presence of symptoms correlated significantly with abnormal chest x-ray findings. In contrast, since subjects in the current study had mostly mild disease in the acute phase with no significant x-ray changes, it is probable that no further abnormalities would have been evident one year later. However, Tarraso et al[29] reported that almost a quarter (23%) of COVID-19 patients with moderate and severe disease had developed fibrotic sequelae on CT scan at 12 months post discharge. Given that CT scans are more sensitive, those subjects that had moderate to severe disease in the current study could have benefited from CT scan investigation.

The current study found no association between COVID-19 disease severity and subjective functional impairment or work ability. Most miners (96%) graded on the PCFS had no limitations in functionality, while 4% had negligible functional limitation. Similarly, scores on the WAI ranged from moderate to excellent with the majority (86%) scoring in the 37 to 43 range. These findings were expected given that the majority of miners reported having a mild form of COVID-19 and returned to work within two weeks, since they were declared fit to work during special return to work medical surveillance examinations. However, one cannot rule out the possibility of reporting bias in that respondents may have responded in the affirmative for fear of a negative answers may have impacted on their level of fitness to work and their job security. However, several studies[5,10,11,30] have reported functional impairment and disability in individuals with mild COVID-19 disease.

A common finding in a number of COVID-19 studies is the development of persistent fatigue and cognitive impairment post infection. A systemic review and metanalysis[31] of 81 studies established that approximately a third of individuals experienced persistent fatigue and over a fifth exhibited cognitive impairment 12 or more weeks following COVID-19 diagnosis. While the current study found that 15% of the miners reported delayed return to work due to acute SARS-CoV-2 infection, all miners in this study had resumed active duty and were fit to work without restrictions. The divergence of these findings from other studies[5,10,11,30] could be explained by the healthy worker effect. In this study the miners that were recruited from the occupational health unit, were healthy and fit employees in active duty. The study did not include unfit employees that were either temporary unfit, hospitalised, undergoing rehabilitation or dismissed through the medical incapacity process.

In the current study, COVID 19 disease severity was not associated with an impaired TMWT. Only female sex was associated with impaired TMWT after adjusting for other covariates. Since no baseline pre-COVID-19 TMWT data were available, an association between poor performance on the TMWT and COVID-19 infection could not be investigated. In contrast, other studies (using the six-minute walk test) were able to demonstrate a high prevalence of impairment in COVID-19 survivors regardless of severity of disease[32]. Gunnarsson et el[32] showed that 23% of individuals had an impaired 6MWT. They further demonstrated that in addition to female sex, shorter height and higher body weight, and cognitive impairment was a contributing factor for reduced walking distance. Wong et al[1] also reported that patients with moderate or severe COVID-19 disease ($p = 0.004$) had a lower 6MWT distances compared to those with mild disease ($p = 0.040$), but no difference was found between moderate and severe groups ($p = 0.550$). The study also found that dyspnoea and hypoxemia were also associated with reduced distances, suggesting that these symptoms may have distinct mechanisms through which they impact on functional capacity. While the current study findings were not consistent with earlier studies overall, female sex was associated with poor performance on the TMWT similar to with the findings of Gunnarsson et al[32]. It is possible that higher BMI may have also been correlated with female sex. Finally, given the relatively younger age of the subjects in the current study, the 6MWT may have been a better and more sensitive test to assess functional ability in these miners.

Study strengths and limitations

To our knowledge, this is one of few studies in South Africa to investigate functional capacity and work ability post SARS-CoV-2 infection in an open cast mining environment. Complete and updated COVID-19 data was available on all miners since all mines were legally obligated to record COVID-19 and medical surveillance data.

Despite the large workforce in the ferromanganese mine, only a small sample (n=204) of miners were successfully recruited compared to other studies with larger study populations, contributing to the reduced power for statistical analysis to investigate associations. The study was also unable to fully evaluate respiratory impairment through the use of spirometry due to COVID-19 restrictions that prohibited the use of spirometry during medical surveillance. The study did not investigate the presence of persistent symptoms beyond 12 weeks and PCS. Various forms of bias could have further contributed, including recall bias that could have led to under reporting of symptoms. Reporting bias may have also have occurred since workers may have withheld certain information due to concerns that this information may negatively affect their future employment or earnings. Selection bias was present in the form of the healthy worker effect, since only workers who were fit to work were recruited. The findings of this study may not be generalizable to the larger mining sector due to the relatively small sample size and selection biases.

Recommendations

Currently, the mining sector in South Africa lacks evidence-based approaches in monitoring employee's post-pandemics for changes in work ability or fitness to work post-infection. Targeted longitudinal research on the impact of SARS-CoV-2 infection and PCS is required to inform return to work assessment procedures and rehabilitation policies particularly in labour intense industries such as mining and construction. This study further highlights the importance of a well-coordinated and structured pandemic management approach (contact tracing, home visits, PCR testing, early referrals, vitamin supplements) and ongoing surveillance as by the mining industry, which resulted in quality COVID-19 data being available for further analysis. This template can be adopted by public health authorities to improve outcomes during future pandemics.

CONCLUSION

In conclusion, this study found limited evidence of impaired functional capacity and work ability in miners following COVID-19 disease within one year of infection with SARS-CoV-2. Furthermore, only female sex, but not COVID-19 disease severity, was associated with impaired functional ability as determined by the TMWT. While females had reduced walking distances on the exercise tolerance test (TMWT) it is not possible to infer that this was due to COVID-19 in the absence of pre COVID-19 data as a basis for comparison.

KEY MESSAGES

1. Exercise endurance and work ability in miners who returned to work was not affected irrespective of COVID-19 severity 12 months after infection. This however, may be indicative of the healthy worker effect phenomenon.

2. There were no differences in functional capacity and work ability between previously healthy miners compared to those with comorbidities.

3. Exercise endurance, as measured by the Two-Minute Walk Test distance, was significantly decreased in female miners with COVID-19 disease 12 months after infection.

4. The scientific literature is replete with data on the natural history of COVID-19 and its effects on work ability in adults performing white collar work, but scanty on studies of workers employed in labour-intensive industries such as mining and construction.

5. Return to work health programmes must be resilient and responsive to pandemics/epidemics of a similar nature, and tailored to better assess impairment and work ability through ongoing surveillance of high-risk workers.

ACKNOWLEDGEMENTS

This work was supported financially by the Foundation for Human Rights in South Africa.

We wish to thank the mining company management for access to the mine employees and all participants that took part in the study.

DECLARATION

The authors declare that this is their own work, all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

AUTHOR CONTRIBUTIONS

• Conception and design of the study (VN; MJ; IN)

• Data acquisition (VN)

• Data analysis (RB; VN; MJ; IN)

• Interpretation of the data (RB; VN; MJ; IN)

• Drafting of the paper (VN; MJ; IN)

• Critical revision of the paper (MJ; VN; IN)

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APPENDICES

APPENDIX 1. PERMISSION TO CONDUCT RESEARCH

[redacted]
Postmasburg
8420
South Africa

Our ref [redacted]

Dr Vusi Ndlovu
27 B Francolin Crescent
Gonube
East London
5201

RE: APPROVAL TO CONDUCT RESEARCH AT [redacted]

Dear Dr. V. Ndlovu

I am pleased to inform you that you request to conduct research for your MPHIL at the [redacted] in Occupational Health has been approved. Approval is granted under the following conditions:

- Ensure complete anonymity of the employees selected for the study
- There will be no mention of [redacted] in your study i.e. Reseach site remains anonymous
- Ensure protection of [redacted] intellectual property.
- You sign a Non – disclosure agreement prior to commencing your study
- The employees selected give written informed consent
- There will be no remuneration impacts for [redacted] mine operations as you, the researcher will be responsible for travel and financial needs for the study.
- In any event of breach of the above, [redacted] holds the right to withdraw its consent provided that there are reasonable justifiable grounds for doing so.

Best regards

Approve by

[redacted]

DATE: 21/07/2021

AKNOWLDGED/NOT AKNOWLEDGED
VUSI NDLOVU

DATE: 20/07/21

APPENDIX 2: INFORMATION AND CONSENT FORM.

Determinants of functional capacity and work ability post SARS-CoV-2 infection in miners- 2022

English consent form

Title:
Determinants of functional capacity and work ability post SARS-CoV-2 infection in miners.

Purpose:
This research will provide new knowledge relating to identifying mine workers at risk of developing Long COVID-19 and assist with return to work approaches.

Description of the research project
Should you agree to participate in this study, you will be asked to do the following:

a) Answer a questionnaire made up of three parts asking information about yourself, your work, and changes to your life after getting COVID-19.
b) Measure your height and weight.
c) A chest x-ray to check whether COVID-19 has affected your lungs.
d) An exercise walk test for two minutes to assess your level of fitness. Before and post the walk test, oxygen levels will be recorded.

Confidentiality
Your personal information will be kept strictly confidential. Your name and ID number will not be reported to anyone. Only the research team will have access to your personal information.

Risks and discomforts from the study
Assistance will be provided in completing the questionnaires. The walk test might cause muscle pain and tiredness but you will be allowed to rest after the test or discontinue if you have body pain or lightheadedness. The chest x-ray is the one that is routinely done on you and only exposes you to a small amount of radiation with minimal health risk.

Benefits of the research to you
Your participation will help us to better understand the long term effects of COVID-19. It will help us to develop better ways of re-integrating mine workers back into the workplace after illness with COVID-19 and other similar illnesses. Should you be found to have abnormal results, we will refer you to the Occupational Therapy Department and/or to a specialist for further management.

Cost to you for Participating in the study.
The study is offered to you at no financial cost. We only request some of your time during working hours.

Voluntariness
Participation in the study is completely voluntary. You have the right not to participate or to withdraw at any point during the study without any consequences to yourself.

Contact persons

You may contact the following person with any questions or queries relating to the study:

Dr Vusimuzi Ndlovu (Researcher)
Cell: 0735177112
Office: 0533138156

The Human Research Ethics Committee:
Floor E53, Room 46
Old Main Building, Groote Schuur Hospital
Observatory, 7925
Telephone number: 021 406 6492
UCT study on Determinants of functional capacity and work ability post SARS-CoV-2 infection in miners -2022.

CONSENT FORM IN ENGLISH

STUDY NO. ______________

Consent of the participant

I have read the information given above, or it has been read to me. I understand the meaning of this information, Dr./Mr./Ms.

____

has offered to answer any questions concerning the study. By signing this form, I hereby consent to participate in the study. I also understand that I am free to withdraw from the study at any time without penalty.

Documentation of the consent

One copy of this signed document will be kept together with our research records for this study. A copy of the information sheet about the study can be given to you to keep if requested.

__________________________________ __________________________

Printed name of participant Signature

DATE: ____________________

__________________________________ __________________________

Printed name of researcher taking consent Signature

DATE: ____________________

APPENDIX 3: SOCIODEMOGRAPHIC QUESTIONNAIRE.

Determinants of functional capacity and work ability post COVID-19 infection in miners.

PERSONAL INFORMATION.

Survey number : ________________________

Date of birth : ___/____/______

Sex:
- Male ☐
- Female ☐
- Prefer not to state ☐

Social status:
- Living alone ☐
- Living with spouse/partner ☐

Education level: which levels/grades are these?
- Primary ☐
- Secondary ☐
- Tertiary ☐

Smoking status
- Current ☐
- Former ☐
- Never ☐
- If current smoker, Number of cigarettes per day? ☐

Do you drink alcohol? **<u>Y / N</u>**
- Current ☐
- Former ☐
- Never ☐
- If current drinker, Number of drinks per week? ☐

<u>Acute COVID 19 characteristics:</u>

Predominant symptoms:
- Sore throat ☐
- Cough ☐
- Loss of smell ☐
- Loss of taste ☐
- Shortness of breath ☐

OTHER PLEASE SPECIFY:

OCCUPATIONAL INFORMATION:
Occupation: ________________________________

Department working in

- Mining ☐
- Engineering ☐
- Plant ☐
- SHE ☐
- Workshop ☐

Work schedule

- Shifts ☐
- Straight schedule ☐

Do you work overtime?

Yes	No

If **Yes**, how many hours per week? ____________________

Change of job in past 2 years?

Yes	No

Change due to COVID-19?

Yes	No

If **No,** state reason:
____
____

COVID-19 HISTORY
How many times have you had COVID 19? __________

Date of diagnosis
- First episode infection? ___/____/______
- Second episode? ___/____/______

Severity:	Hospital Admission ☐	More than 3 symptoms, NOT hospitalized ☐	Mild / No symptoms ☐

Method of diagnosis: Symptoms/ PCR/ Antigen Test

Date of other episodes: ___/____/______

Severity:

Hospital Admission ☐	More than 3 symptoms, NOT hospitalized ☐	Mild / No symptoms ☐

Have you received a COVID-19 vaccine?

Y	**N**

Date of vaccination/last dose: ___/____/______

MEDICAL HISTORY

Do you have a chronic medical illness? Yes / No

If Yes, please tick below

DIABETES	☐
HYPERTENSION	☐
HIV/AIDS	☐
ASTHMA	☐
TUBERCULOSIS	☐
COPD	
OTHER	PLEASE SPECIFY:

OCCUPATIONAL DISEASE HISTORY

When did you return to work after your first COVID-19 diagnosis?

- 10-14 days isolation period ☐
- 14-28 days ☐
- > 1 month ☐

Reasons for delayed return to work

- Hospitalized in ward ☐
- Hospitalized in ICU ☐
- Other ☐

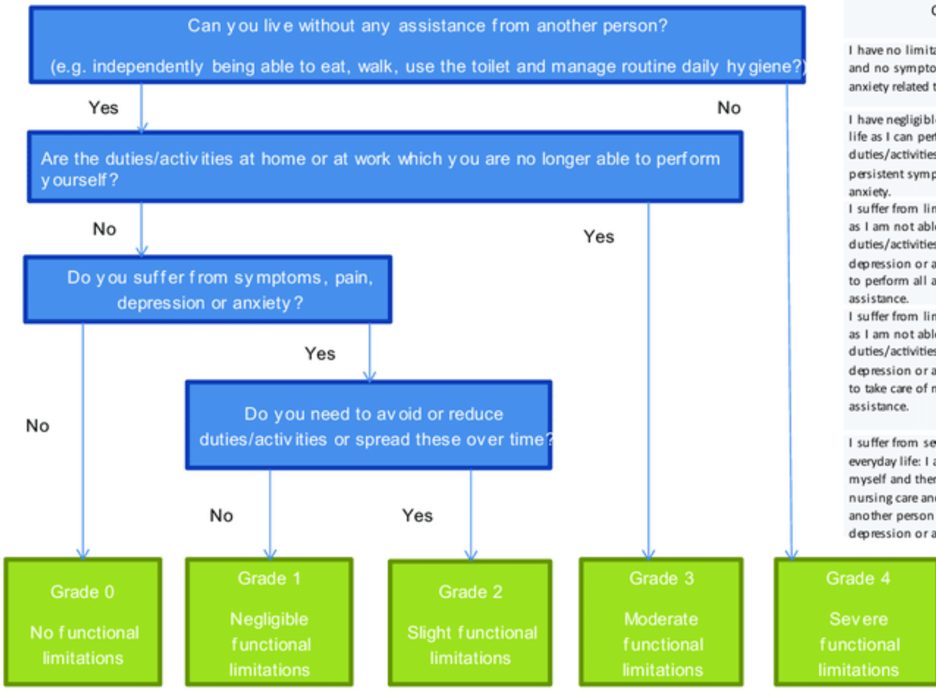
Have you ever been diagnosed with any of the following (tick applicable)?

Silicosis ☐
Asbestosis ☐
Siderosis ☐
Coal workers pneumoconiosis ☐
Berylliosis ☐
Occupational tuberculosis ☐
COPD

Other respiratory disease

PLEASE SPECIFY:

APPENDIX 4 : POST COVID FUNCTIONAL SCALE



How much are you currently affected in your everyday life by COVID-19?	Grade
I have no limitations in my everyday life and no symptoms, pain, depression or anxiety related to the infection.	0
I have negligible limitations in my everyday life as I can perform all usual duties/activities, although I still have persistent symptoms, pain, depression or anxiety.	1
I suffer from limitations in my everyday life as I am not able to perform all usual duties/activities due to symptoms, pain, depression or anxiety. I am, however, able to perform all activities without any assistance.	2
I suffer from limitations in my everyday life as I am not able to perform all usual duties/activities due to symptoms, pain, depression or anxiety. I am, however, able to take care of myself without any assistance.	3
I suffer from severe limitations in my everyday life: I am not able to take care of myself and therefore I am dependent on nursing care and /or assistance from another person due to symptoms, pain, depression or anxiety.	4

APPENDIX 5: THE WORK ABILITY INDEX

Is your work	
Psychologically demanding?	○
Physically demanding?	○
Physically and psychologically demanding?	○

1. Current work ability compared to highest work ability ever:

Assume that your work ability at its best has a value of 10 points. How many points would you give your current work ability?
(0 means that you currently cannot work at all) (10 work ability at its best)

0	1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○	○

2. Work ability in relation to demands

How do you rate your current work ability with respect to the physical demands of your work?

Very good (5)	Rather good (4)	Moderate (3)	Rather poor (2)	Very poor (1)
○	○	○	○	○

How do you rate your current work ability with respect to the mental demands of your work?

Very good (5)	Rather good (4)	Moderate (3)	Rather poor (2)	Very poor (1)
○	○	○	○	○

3. Current diseases

In the following list, mark your current diseases or injuries. Also indicate whether a physician has diagnosed or treated these diseases.		Yes, own opinion (2)	Yes, physician's diagnosis (1)	No (0)
01	Injury due to an accident	○	○	○

02	Musculoskeletal disease in back, limbs or other part of the body (e.g. repeated pain in joint muscle, sciatica, rheumatism, arthritis)	○	○	○
03	Cardiovascular disease (e.g. hypertension, coronary heart disease)	○	○	○
04	Respiratory disease (e.g. repeated infections of the respiratory tract, emphysema)	○	○	○
05	Mental disorder (e.g. depression, "burn-out", anxiety or insomnia)	○	○	○
06	Neurological or sensory disease (e.g. hearing or visual disease, migraine, epilepsy)	○	○	○
07	Digestive disease / condition (e.g. gastritis, gall stones, liver or pancreatic disease, repeated constipation)	○	○	○
08	Genitourinary disease (e.g. infection in urinary tract, gynecological disease or prostate)	○	○	○
09	Skin disease (e.g. allergic or other rash, varicose veins)	○	○	○
10	Tumour or cancer	○	○	○
11	Endocrine or metabolic disease (e.g. diabetes, severe obesity or gout)	○	○	○
12	Blood diseases (e.g. anemia, other blood disorder or defect)	○	○	○
13	Birth defects	○	○	○

14	Other disorder or disease	○	○	○

4. Estimated work impairment due to diseases

Is your illness or injury a hindrance to your current job? Check more than one alternative if needed.

There is no hindrance / I have no diseases.	6
I am able to do my job, but it causes some symptoms.	○ 5
I must sometimes slow down my work pace or change my work methods.	4
I must often slow down my work pace or change my work methods.	○ 3
Because of my condition, I feel I am able to do only part time work.	2
In my opinion I am entirely unable to work.	○ 1

5. Illness within last year (12 months)

During the last 12 months:
how many whole days have you been off work because of illness:

None (5)	Max. 9 days (4)	10 - 24 days (3)	25 - 99 days (2)	100 - 354 days (1)
○	○	○	○	○

6. Estimation of own work ability in 2 years

Do you believe, according to your present state of health, that you will be able to do your current job two years from now?

Unlikely (1)	Not Certain (4)	Relatively certain (7)
○	○	○

7. Mental capacities

7.1 | Considering the last three months: Have you been able to enjoy your regular daily activities?

Often (4)	Rather often (3)	Sometimes (2)	rather seldom (1)	Never (0)
○	○	○	○	○

7.2 | Considering the last three months: Have you been active and alert?

Often (4)	Rather often (3)	Sometimes (2)	rather seldom (1)	Never (0)
○	○	○	○	○

7.3 | Considering the last three months: Have you felt yourself to be full of hope about the future?

Often (4)	Rather often (3)	Sometimes (2)	rather seldom (1)	Never (0)
○	○	○	○	○

WAI Grading System

The table below represents the grading system and recommended intervention:

Points	Work Ability	Objective of Measures
7 - 27	Poor	Restore work ability
28 - 36	Moderate	Improve work ability
37 - 43	Good	Support work ability
44 - 49	Excellent	Maintain work ability

APPENDIX 6: CLINICAL ASSESSMENT

1. BMI: weight_____kg and height _____cm

2. Chest x-ray findings?

Pre COVID-19:	
Normal	☐
Abnormal	☐

If abnormal: ILO classification findings and diagnosis ______________________

Post COVID-19: compared to pre-Covid

Normal – Normal (previously)	☐
Abnormal – no new changes	☐
Abnormal – new changes noted	☐

All abnormal: ILO classification findings and diagnosis ______________________

APPENDIX 7 ILO XRAY GRADING.

ILO X-RAY READING FORM

Reader: ____________ X-ray date: ________ Film quality: | 1 | 2 | 3 | UR |

Name: ____________ Age: ________

Co. No. ________

Occupational history: ____________

Smoker: | Yes | No | Ex |

A. PARENCHYMAL ABNORMALITIES

Yes=1, No=2 ☐

Small Opacities

Primary	
p	s
q	t
r	u

Secondary	
p	s
q	t
r	u

Zones	
R	L

Profusion			
0	0/-	0/0	0/1
1	1/0	1/1	1/2
2	2/1	2/2	2/3
3	3/2	3/3	3/+

Large Opacities

0	A	B	C

B. PLEURAL CHANGES

☐

Pleural Thickening

Diaphragm (plaque)

SITE:	0	R	L

Circumscribed (plaque)

SITE		R				L			
IN PROFILE	Width	0	a	b	c	0	a	b	c
	Extent	0	1	2	3	0	1	2	3
FACE ON		0	1	2	3	0	1	2	3

Costophrenic Angle

SITE:	0	R	L

Diffuse

SITE		R				L			
IN PROFILE	Width	0	a	b	c	0	a	b	c
	Extent	0	1	2	3	0	1	2	3
FACE ON		0	1	2	3	0	1	2	3

Pleural Calcification

☐

SITE	R				L			
DIAPHRAGM	0	1	2	3	0	1	2	3
WALL	0	1	2	3	0	1	2	3
OTHER SITES	0	1	2	3	0	1	2	3

C. TUBERCULOSIS

☐

Comment: ____________

OTHER SYMBOLS

☐

Comment: ____________

o	ax	bu	ca	cn	co	cp	cv
ef	em	es	fr	hi	ho	id	ih
pi	px	rp	tb	di	kl	od	

Date:

APPENDIX 8: THE TWO MINUTE WALK TEST

INSTRUCTIONS

Two Minute Walk Test Instructions

- **General Information:**
- Pre-TMWT oxygen saturation recorded (Discontinue TMWT if Sats <90%)
- individual walks without assistance for 2 minutes and the distance is measured
- start timing when the individual is instructed to "Go"
- stop timing at 2 minutes
- assistive devices can be used but should be kept consistent and documented from test to test
- if physical assistance is required to walk, this should not be performed
- a measuring wheel is helpful to determine the distance walked
- should be performed at the fastest speed possible
- Post-TMWT oxygen saturation is to be recorded.

Set-up and equipment:
- ensure the hallway free of obstacles
- stopwatch

Patient Instructions:
"Cover as much ground as possible over 2 minutes. Walk continuously if possible, but do not be concerned if you need to slow down or stop to rest. The goal is to feel at the end of the test that more ground could not have been covered in the 2 minutes."

Record participant findings (select age and gender then enter distance walked)

	Male	Female	Distance walked (meters)
Age 20 - 29			
Age 30 - 39			
Age 40 - 49			
Age 50 - 59			
Age 60 - 69			
Age 70 - 79			

Normative reference values for the two minute walk test

Table 2. Summary of two-minute walk test distance stratified by gender and age from four studies

Group (n)	Bohannon (2017) Mean (SD) [n]	Bohannon, et al. (2015) Mean (SD) [n]	Priya & Verma (2015) Mean (SD) [n]	White et al. (2014) Mean (SD) [n]	Consolidated		
					Weighted Mean (SE) [n]	95% CI	I^2
Men 20–29	219.6 (25.0) [10]	210.2 (28.8) [67]	225.4 (26.4) [31]		217.9 (5.4) [108]	207.2–228.6	0.00
Women 20–29	203.2 (15.3) [10]	180.7 (24.9) [171]	199.9 (24.4) [22]		194.1 (8.4) [203]	177.7–210.5	0.00
Men 30–39		201.4 (29.7) [74]	204.2 (28.3) [24]		202.1 (3.0) [98]	196.3–207.9	0.00
Women 30–39		181.8 (27.1) [215]	179.3 (26.0) [33]		181.4 (1.7) [248]	178.1–184.8	0.00
Men 40–49		191.1 (30.1) [85]	194.6 (27.9) [31]		192.1 (2.7) [116]	186.8–197.5	0.00
Women 40–49		183.3 (29.4) [151]	170.3 (18.3) [38]		180.7(10.4) [189]	160.3–201.0	0.00
Men 50–59		189.1 (28.7) [73]	190.9 (20.4) [25]		189.8 (2.6) [98]	184.7–194.9	0.00
Women 50–59		178.8 (22.6) [99]	158.8 (24.1) [31]		169.1 (10.0) [130]	149.6–188.7	0.00
Men 60–69	219.5 (28.7) [4]	177.3 (34.2) [60]	174.9 (19.4) [30]		183.0 (7.0) [94]	169.3–196.8	61.3
Women 60–69	184.5 (25.0) [6]	161.9 (29.7) [75]	151.7 (25.9) [18]		163.7 (6.9) [99]	150.0–177.3	36.5
Men 70–79	183.9 (27.2) [6]	164.4 (30.1) [59]	138.7 (28.2) [13]	167.7 (30.1) [1,131]	163.1 (5.3) [1,209]	152.7–173.5	55.1
Women 70–79	166.3 (29.6) [4]	145.4 (27.5) [56]	153.3 (16.2) [4]	150.7 (27.9) [1,124]	150.3 (1.3) [1,188]	147.7–152.9	0.00

APPENDIX 9: ETHICS APPROVAL

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room 45 E-52-E-Floor- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

26 July 2022

HREC REF: 303/2022

Prof M Jeebhay
Division of Occupational Medicine
Falmouth Building-FHS
Email: mohamed.jeebhay@uct.ac.za
Student: drvusindlovuomp@gmail.com

Dear Prof Jeebhay

PROJECT TITLE: **DETERMINANTS OF FUNCTIONAL CAPACITY AND WORK ABILITY POST SARS-COV-2 INFECTION IN MINERS**
(MPHIL DEGREE – DR VUSIMUZI NDLOVU)

Thank you for your response letter, addressing the issues raised by the Faculty of Health Sciences Human Research Ethics Committee (HREC). f

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 July 2023.

Please submit a progress form, using the standardised Annual Report Form (FHS016) if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: - Dr Vusimuzi Ndlovu will also be involved in this study.

Please quote the HREC REF 303/2022 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637. Institutional Review Board (IRB) number: IRB00001938 NHREC-registration number: REC-210208-007

HREC/ref 303.2022

APPENDIX 10: RESEARCH PROTOCOL

Determinants of functional capacity and work ability post SARS-CoV-2 infection in miners

A RESEARCH PROTOCOL

BY: DR VUSIMUZI NDLOVU

STUDENT NUMBER: NDLVUS004

SUPERVISORS: PROF MJ JEEBHAY AND DR IMT NTATAMALA

TABLE OF CONTENTS.

ABBREVIATIONS

AIDS:	ACQUIRED IMMUNODEFICIENCY SYNDROME
COPD:	CHRONIC OBSTRUCTIVE PULMONARY DISEASE
COVID-19	CORONAVIRUS DISEASE
CPET	CARDIOPULMONARY EXERCISE TEST
CT	COMPUTED TOMOGRAPHY
CXR:	CHEST X-RAY
D_{LCO}:	DIFFUSION CAPACITY OF LUNG FOR CARBON MONOXIDE
FEV_1:	FORCED EXPIRATORY VOLUME IN 1 SECOND
FVC:	FORCED VITAL CAPACITY
HIV:	HUMAN IMMUNODEFICIENCY VIRUS
ICU:	INTENSIVE CARE UNIT
MERS	MIDDLE EAST RESPIRATORY SYNDROME
MPHIL:	MASTER OF PHILOSOPHY
LMIC	LOW-TO-MIDDLE-INCOME COUNTRY
6MWT:	6 MINUTE WALK TEST
OMP	OCCUPATIONAL MEDICAL PRACTITIONER
OHNP	OCCUPATIONAL HEALTH NURSING PRACTITIONER
PCFS:	POST COVID-19 FUNCTIONAL SCALE
PCR:	POLYMERASE CHAIN REACTION
PFT:	PULMONARY FUNCTION TEST
RFA:	REHABILITATION AND FUNCTIONAL ASSESSMENT
SARS-COV-2:	SEVERE ACUTE RESPIRATORY SYNDROME CORONA VIRUS 2
TB:	TUBERCULOSIS
TMWT:	TWO MINUTE WALK TEST
$V'_{O2\ PEAK}$:	PEAK OXYGEN UPTAKE

SUMMARY

While previous studies have focused on the acute manifestations of COVID-19, insufficient data exists on the sequelae of COVID-19 including Long COVID-19 and its impact on affected workers and their rehabilitation needs post-SARS-CoV-2 infection. There are a few studies in the broader population, which show that a proportion of COVID-19-affected individuals develop persistent symptoms that may impact on activities of daily living and their ability to return to gainful employment. It is estimated that over one-third of individuals with COVID-19 experience chronic dyspnea two to three months after infection resulting in a reduced quality of life. The effect of Long COVID-19 on workability and fitness to work remains largely unknown, especially in the South African mining sector, which is known to have a high burden of silicosis and tuberculosis.

This cross-sectional study sought to investigate the determinants of functional capacity and workability in miners following COVID-19 disease. In this study, miners working in an iron ore mine in Postmasburg in the Northern Cape were invited to participate by completing a questionnaire including a sociodemographic questionnaire; Post COVID-19 Functional Scale (PCFS) and Work Ability Index (WAI). A chest radiograph was analysed for the presence of new abnormalities post COVID-19 and a two-minute walk test (TMWT) was done to assess exercise tolerance.

The findings of this study identified the ability of workers post COVID-19 to work and identified their exercise tolerance, their rehabilitation needs, which may include alternative accommodation options for employees deemed unfit to return to their pre-COVID-19 occupations. The findings will also inform mining sector policymakers on return to work assessment procedures in low-to-middle-income countries (LMIC) such as South Africa.

A) INTRODUCTION AND BACKGROUND

A previous review of the COVID-19 pandemic in South African mines suggested that aside from the migrant labour system, socio-geographic factors such as poor housing conditions and mining exposure factors such as poorly ventilated shafts coupled with the presence of co-morbid occupational lung diseases (silicosis, tuberculosis (TB), and chronic obstructive pulmonary disease (COPD) and HIV, may be a risk factor for severe COVID-19 disease[1]. Acute infection with the SARS-COV-2 virus results in a disease of the varying spectrum both in severity and in organs affected. The majority of infected patients (81%) get mild symptoms whereas about 14 % develop severe illness[2]. Globally, it is estimated that 20% of individuals develop chronic symptoms commonly called Long COVID-19 at 4 weeks and 10% continue to have symptoms at 3 months post-SARS-COV-2 infection[2]. Among these individuals, it is estimated that almost half (47%) of individuals have fatigue and a third (32%) experience shortness of breath[2].

There is a paucity of data to inform workplace policies of workers with Long COVID-19 returning to work after moderate to severe disease, especially those that are hospitalized. In the mining sector, where workers are frequently exposed to dust particulate, fumes and chemical vapours affecting lung health, questions regarding fitness to work for this group remain unanswered.

There is therefore a need to better understand these aspects in order to address the long-term consequences of COVID-19 on the health of miners and optimize their reintegration into the world of work. Occupational medical practitioners are ideally placed in occupational health centers to conduct such research given the large size of the labour force, more so in the mining sector, which employs over 450 000 employees.

B) LITERATURE REVIEW

Introduction

The COVID-19 pandemic caused by the SARS-CoV-2 virus has had a significant impact on many workers in various economic sectors, including mining. By April 2022, the mining sector in South Africa had recorded over 63 900 cases of employees infected with the SARS-Cov-2 virus[3]. Mortality of over 749 employees was reported while 336 502 employees had been vaccinated. Mining-related COVID-19 cases account for 2% of total caseload and slightly less than 1% of total fatalities in South Africa Although 98% of those infected had recovered, the 1.4 % that died and those with persistent post-COVID-19 symptoms remain a course for concern for the sector[3].

Factors postulated to be associated with increased risk of SARS-CoV-2 infection in the mining sector include poor living and working conditions in mines where overcrowded living spaces and underground work necessitates close contact including difficulties in enforcing infection prevention and control measures[1] The platinum mines in the North West Province for example have consistently recorded the highest numbers of positive cases of Sars-CoV-2 driven largely by the migration of workers from hot spots such as Gauteng and the Eastern Cape, overcrowded living quarters and the conditions underground such as overcrowding and poor ventilation.

An ongoing concern for employers in labour-intense economic sectors such as mining and construction has been the impact of COVID-19 on the workers' ability to return to work and to fulfil the inherent requirements of their occupation. The impact of the disease on both the workforce and ultimately production is of concern. In a recent review, Naidoo and Jeebhay**Error! Bookmark not defined.** proposed that COVID-19 may be a new burden of respiratory disease among South African miners and argued that COVID-19 and Long COVID-19 are likely to have far-reaching consequences on fitness to work, work ability including job security and income for mine workers. They further highlighted the need for rehabilitation and an individualized return to work plan and monitoring of survivors.

Objectives of the review

1. To describe the prevalence of Long COVID-19 in employees working in labour-intensive industries such as mining and construction.
2. To identify studies on the determinants of Long COVID-19, especially in relation to cardiorespiratory function.
3. To identify studies on the determinants of reduced functional capacity and workability post-SARS-CoV-2 infection in miners and/or construction workers.
4. To evaluate the fitness requirements for workers, post COVID-19 disease for workers in labour-intensive industries such as mining and construction

Search Strategy

An extensive literature search was conducted using databases such as PubMed and Ebsco Host. Further information was also obtained from Google Scholar and reports in the grey literature such as the Minerals Council of South Africa.

A three-step approach was used to ensure that only relevant articles were shortlisted. The first step was to identify articles through the electronic databases named above. Step 2 was the sorting process where titles and abstracts were screened for relevance. The final step in the literature search was applying inclusion and exclusion criteria to ensure eligibility. The inclusion criteria were availability in English, emphasis on Long COVID-19 and workability or disability, and COVID-19 in mining and/or construction. Articles were excluded if their focus was on organ systems other than the cardiorespiratory system.

The following keywords were used in the literature search:

COVID-19 OR Sars-Cov-2 OR long COVID-19 OR long haulers OR post COVID-19 syndrome OR Post-acute COVID-19 OR chronic COVID-19 AND cardiorespiratory effects OR cardiorespiratory endurance OR cardiorespiratory fitness OR cardiorespiratory function OR functional capacity OR workability OR exercise capacity OR exercise endurance AND Disability OR disabled OR disabilities OR inability OR impairment AND miners OR mining OR construction AND South Africa

Over 50 articles were originally obtained using keyword search. Language and subject content were used as exclusion criteria resulting in 26 articles finally being included for review. Of the 26 articles included, 23 were used in the body of the literature review, while 3 were used in the methodology. The following flow diagram illustrates the literature search process:

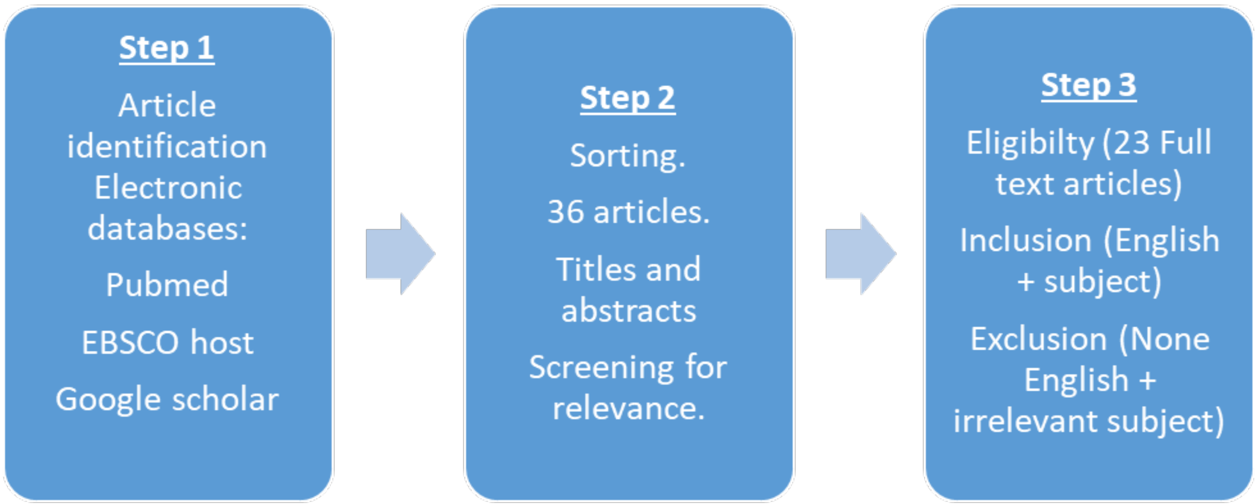


Figure 1: Flow diagram showing the search strategy

I. Nosology of Long COVID-19

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative pathogen for COVID-19 has been reported to affect multiple organ systems. Early evidence suggests that pulmonary, cardiovascular, gastrointestinal, neuropsychiatric, renal, and haematological systems are the most commonly affected. While it is now known that approximately 10% of COVID-19 infected patients fail to recover fully and experience persistent symptoms post COVID-19[4], the spectrum of Long COVID-19 is not well characterized.

The World Health Organization (WHO) defines this post COVID-19 condition as occurring in individuals with a history of probable or confirmed SARS CoV-2 infection, usually "3 months from the onset of COVID-19 with symptoms and that last for at least 2 months and cannot be explained by an alternative diagnosis"[5]. The most common symptoms include fatigue, sleep disturbance, shortness of breath, and cognitive and psychosocial dysfunction, which have an impact on everyday functioning. Symptoms may be new onset following initial recovery from an acute COVID-19 episode or persist from the initial illness. Symptoms may also fluctuate or relapse over time.

Carfi et al[4] demonstrated earlier on in the pandemic that fatigue (53%) and breathlessness (43%) were the most common symptoms in patients up to 7 weeks post-discharge. Reasonable deductions can be made from experiences with other coronaviruses that have caused pandemics in the past such as SARS-CoV-1 reported in 2002 and Middle East Respiratory Syndrome (MERS) in 2012. Up to 25% of those infected by SARS-CoV-1 and MERS were shown to have reduced lung function and exercise capacity up to six months post-hospital discharge. With these lessons from SARS-CoV-1 and MERS and the new evidence, it is reasonable therefore to anticipate that SARS–CoV-2 infection is likely to follow a similar trajectory in terms of post-acute sequelae.

Consensus has since been reached regarding the definition of Long COVID-19 following the definition adopted by the WHO. Prior to the WHO definition, Nabavi[5] defined Long COVID-19 as "not recovering [for] several weeks or months following the start of symptoms that were suggestive of COVID-19, whether you were tested or not". The National Institute for National Health and Care Excellence (NICE) classified the post-COVID-19 condition into two broad groups based on the time from onset of symptoms. In this classification, ongoing symptomatic COVID-19 was defined as signs and symptoms of COVID-19 from 4 to 12 weeks, Post-COVID-19 syndrome is defined as signs and symptoms that develop during or after an infection consistent with COVID-19, continue for more than 12 weeks, and are not explained by an alternative diagnosis. South Africa's National Institute of Communicable Diseases (NICD) however defined Long Covid-19 as 'Persons with COVID-19 who experience symptoms for greater more than 28 days from diagnosis (whether laboratory or clinical)". Notably, earlier definitions emphasized the requirement for a positive PCR test, but the realization that accessibility, availability, false-negative tests and other factors made it impractical to do PCR testing on all patients, which led to the inclusion of clinical diagnoses in the current definition.

Perhaps the most detailed classification was that proposed by Fernández-de-Las-Peñas et al[6]. These researchers adopted a definition of Long COVID-19 from earlier work done by Sivan and Taylor who defined Long COVID-19 as "signs and symptoms that continue for more than 4 weeks and can be attributed to COVID-19 infection". Fernández-de-Las-Peñas et al[6] proposed four phases based on a timeline from the onset of acute symptoms to beyond 24 weeks. They grouped survivors into 3 groups, 'none -hospitalized', 'hospitalized' and 'asymptomatic'. They proceeded to classify survivors in each group into four phases viz. transition phase (described as the acute stage – diagnosis to 5 weeks), phase 1 (described as post-acute – 5 to 12 weeks), phase 2 (described as Long COVID-19 – 12 to 24 weeks) and phase 3 (described as persistent post-COVID-19 – beyond 24 weeks).

II. Prevalence of Long COVID-19

Due to the lack of a common definition and the heterogeneity of the condition of Long COVID-19, the true prevalence of the condition is unknown. The few available studies differed in methodology, study populations and definitions of COVID -19 positivity. A study done by the Office for National Statistics in the United Kingdom in 2020[2], reported that 21% of patients with COVID-19 had symptoms 5 weeks after infection and 10 % had symptoms 12 weeks after infection. Sudre et al[7] using data from a cellphone application in the United Kingdom found that 13 % of individuals had symptoms lasting 28 days after symptom onset and 5% had symptoms for over 8 weeks. Only 2 % had symptoms for more than 12 weeks after symptom onset.

Goertz et al[8] showed that among the 2113 cases in the Netherlands and Belgium, more than 99% of infected individuals failed to recover completely within 12 weeks after the onset of symptoms. The populations surveyed in these studies varied greatly since they included patients with mild and moderate symptoms most of whom were not hospitalized compared to other studies reported of patients with severe diseases needing hospitalization. Furthermore, the sampling method used may also account for the differences in reported data. However there now exists enough evidence to prove the existence of the condition of Long COVID-19.

III. Long COVID-19 Symptoms

Similar to SARS-CoV-1 and MERS, the Sars-CoV-2 virus has been shown to affect almost every organ system in humans, leading to a broad spectrum of presenting symptoms. Ayiegbusi et al[9] in their systematic review of primary research studies of Long COVID-19 found persistence of a number of symptoms in patients affecting the cardiopulmonary, nasopharyngeal, musculoskeletal and neuropsychological systems. Among the ten most prevalent symptoms reported fatigue (47%) and dyspnea (32%). Other symptoms included myalgia (25%), joint pain (20%), headache (18%), cough (18%), chest pain (15%), altered smell (14%) and taste (7%) and diarrhoea (6%).

Dryden et al[10] reported on a longitudinal study of hospitalized COVID-19 patients in South Africa in which patients were interviewed at 1, 3, 6, and 12 months and investigated COVID-19 in relation to comorbidities, persistent symptoms, severe symptoms, age, race and sex. The study showed that over 30% of patients had more than 4 persistent symptoms at 1month post diagnosis and that fatigue, shortness of breath, headache and limb muscle weakness were the most commonly reported symptoms, in keeping with other studies as reported by Ayiegbusi et al**Error! Bookmark not defined.**. Dryden et[10] also found that over 60% of patients (post-COVID-19) experienced shortness of breath on strenuous exercise and that among the group of patients that changed occupation post-COVID-19, 70 % of them reported Long COVID-19 to be the reason.

Huang et al[11] assessed COVID-19 patients at 6 months post-hospital discharge in a Chinese cohort study utilising various modalities that included questionnaires, physical examinations, 6-minute walk test, computed tomography (CT) chest scans and ultrasonography. The study found that women reported symptoms more frequently than men and that 76% of patients had at least 1 symptom at 6 months. Fatigue or muscle weakness was also the most commonly reported symptoms (63%) followed by sleep difficulties at 26%. Other common symptoms reported in this study were anxiety and depression, particularly in women.

A Norwegian cohort study of only ‘none hospitalized’ patients by Stavem et al[12] found that the majority of patients (>50%) had no symptoms at 1.5 and 6 months. Among those that had symptoms the most common was dyspnea (15 %) followed by anosmia (12%) and dysgeusia at 10%.

IV. Determinants of Long COVID-19 and effects on cardiorespiratory function

There is a paucity of data on the prevalence and risk factors for Long COVID-19. A few studies have reported increasing age, increased body mass index (BMI), female sex, symptom load during the acute phase (>5 symptoms) as risk factors for Long COVID 19[9].

Jacobson et al[13] followed up 118 patients at 3 – 4 months after their initial COVID-19 diagnosis to assess the prevalence of persistent functional impairment post-COVID-19. The study found that black participants and those having fever/chills or cough at onset were more likely to have poor results on the 6-minute walk test suggesting underlying cardiorespiratory impairment.

While COVID-19 primarily affects the respiratory system but it is not uncommon for the cardiac system to be affected as well. It is probable that fatigue, the most common symptom in long COVID-19 may be due to the impact of Sars-CoV-2 on these two systems. A Norwegian study by Skjørten et al[14] of a previously hospitalized group (n=156) to a reference population 3 months post hospital discharge confirmed the presence of cardiorespiratory compromise among those with the previous infection from COVID-19 that were hospitalized. It demonstrated that a third of the patient group had a VO2 peak < 80% compared to the control population. This has also been reported in other similar studies[;12]. Furthermore, the study also found that a lower VO2 peak was the only major finding in the dyspnea group compared to the non-dyspnea group, whereas the other components of the Cardiopulmonary Exercise Test (CPET) assessment such as ventilation, breathing reserve and SpO2 were similar.

Table 1 summarizes the studies that have investigated the prevalence and risk factors of Long COVID-19.

Table 1. Prevalence and risk factors of Long COVID-19 symptoms and cardiopulmonary findings of selected studies.

Study Author, Year	Population (n)	Prevalence of Long COVID-19 symptoms	Factors significantly associated with Long COVID-19	Cardiopulmonary assessment tools	Findings
Skjørten et al[14](2021)	Hospital outpatients (n=156)	Not investigated	Not investigated	CPET, spirometry, DLCO	VO2 peak <80% pred reduced in 31% of patients; ventilatory efficiency reduced in 15% of patients
Shah et al[15] (2020)	Discharged patients (n=60)	Not investigated	Not investigated	Questionnaire, PFT, 6MWT, CT chest	DLCO Abnormality in 52%; $FEV_1/FVC<0.70$ in 11%; SpO_2 <88% post 6MWT in 7%
Rinaldo et al (2021)[16]	Hospital outpatients (n=75)	Not investigated	Not investigated	CT chest, spirometry, CPET	Reduced exercise capacity in 55%
Sudre et al[7] (2021)	Outpatients (14% hospitalized) (n=4182)	Fatigue (97.7%), intermittent headaches (91.2%)	Increasing age, BMI, female, > 5 symptoms in first week	COVID-19 symptom app.	Not investigated
Crameri et al [17](2020)	Army recruits (n=199)	Not investigated	Not investigated	Endurance physical training	>10% VO2 decrease in 19%

Study Author, Year	Population (n)	Prevalence of Long COVID-19 symptoms	Factors significantly associated with Long COVID-19	Cardiopulmonary assessment tools	Findings
Strumiliene et al[18] (2021)	Discharged patients (n=51)	Fatigue (68.6%), reduction of physical activity (60.8%), dyspnea on exertion (54.9%), asthenia (37.3%)	Male, obesity, comorbidities	Questionnaire, 6MWT, PFT	impaired PFT in 47%; reduced physical capacity for 6 MWT in 27%
Stavem, et al[12] (2020)	Discharged patients (n=451)	Dyspnea (16%), loss/disturbance of smell (12%) loss/disturbance of taste (10%)	comorbidities, number of symptoms during the acute phase	Questionnaire	Not investigated
Cort´es-Telles et al[19] (2021)	Noncritical patients (n=186)	Fatigue on effort (67%), dyspnea (38%) myalgia (32%) cough (30%) chest pain (30%) sore throat (17%)	Not investigated	Questionnaire, spirometry, DLCO, 6MWT	Patients with persistent dyspnea had significantly ($p<0.05$) lower FVC, FEV_1, DLCO, 6 MWT (% predicted), end-exercise oxygen saturation, higher Borg ratings

CPET – cardiopulmonary exercise test; DLCO – Diffusion capacity of the lung for carbon monoxide; VO2 peak – Peak oxygen uptake; PFT – Pulmonary function test; 6MWT – 6-minute walk test; CT – Computed tomography; FVC – Forced vital capacity; FEV_1 – Forced expiratory volume in 1 second.

V. Determinants of reduced functional capacity and workability post COVID-19

A detailed review of the studies is presented in Table 1. The study by Skjørten et al[14Error! Bookmark not defined.] found that deconditioning, circulation and ventilatory limitations were the three leading causes of exercise limitations or reduced functional capacity post-COVID-19. This suggests that patients hospitalized or immobilized for extended periods were more likely to develop exercise limitations given the extent of deconditioning. Carfi et al[4] were able to demonstrate the burden of chronic symptoms and the deterioration in the quality of life of COVID-19 survivors. While approximately 50 % of patients had dyspnea at 2 -3 months post-recovery from COVID-19, it is unclear whether this translated into an actual reduction in functional capacity that was significant enough to affect their ability to do activities of daily living and work. Shah et al[15] also demonstrated radiological evidence and pulmonary functional abnormalities 12 weeks post-hospitalization for COVID-19 in more than 50 % of patients in a Canadian study.

An Italian study (n=75) by Rinaldo et al[16], which focused on deconditioning as the major contributing factor for exercise impairment in COVID-19 survivors demonstrated that COVID-19 survivors had a mild reduction in their exercise capacity. However, less than 15% of patients with reduced exercise capacity had a ventilatory and circulatory limitation. This suggests that exercise limitation, and by extension work inability post-COVID-19 has multiple underlying contributory factors. These findings are similar to other studies such as those reported by Gao et al[15] that showed little or no differences in pulmonary function and circulation among those with different grades of exercise limitation.

Crameri et al[17] focused specifically on young army recruits with the intention of assessing the reduction in maximal aerobic capacity post-COVID-19 infection. In this study, 3 groups were compared viz. not infected, asymptomatic and convalescent group at 1 to 2 months post diagnosis with regard to VO2 max pre- and post-COVID-19. The study found that 20% of recruits in the convalescent group showed a significant decrease in VO2 max while none of the recruits in the other groups showed a similar decrease. The researchers concluded that deconditioning and other factors may explain these findings.

Other researchers have used a slightly different methodology in determining exercise capacity post SARS-CoV-2 infection. Strumiliene et al[18] and Cort´es-Telles et al[19] assessed patients 2-3 months post-discharge. In the former study (n=51), only 5.9% of patients were symptom-free at follow-up while the majority (68.6%) complained of fatigue. Furthermore, 27.3% of patients had reduced exercise capacity on the 6MWT and 47.2% had pulmonary function impairment at follow-up. In the latter study (n=186) patients with persistent dyspnea had reduced functional capacity and increased desaturation and exertional symptoms during the 6MWT.

VI. Impact of COVID-19 on work ability and return to work – focus on mining and related construction workers

There were not many studies that reported on work ability and return to work aspects in mining or related construction work. A Swedish study by Schandl et al[20] showed that critically ill patients (admitted to ICU) with COVID -19 previously working full time prior to illness, at 5 months post discharge, only 50% had returned to full time work. Other findings in this study were that about a third of patients at 5 months post COVID-19 had post-traumatic stress, anxiety and depression while 26% and 34% had reduced total lung capacity and six-minute walk test respectively. Possible reasons for failure to return to full functionality can be due to both mental and physical ill health post-COVID-19.

Prior to the COVID-19 pandemic, research has shown that there is a correlation between severe illness and loss of employment. Kamdar et al[21] showed that over 66% of previously employed ICU admitted patients were jobless at 3, 6, 12 and 60 months post-discharge. This was due to post-intensive care syndrome, a well-described condition secondary to ICU interventions such as mechanical ventilation. It is probable that patients with severe COVID-19 disease resulting in Intensive Care Unit (ICU) admission would follow a similar trajectory. These patients would require rehabilitation and fitness to return to work assessment due to poor exercise capacity associated with Long COVID-19.

Conclusion

This literature review has identified that persistent symptoms and impairment up to 6 months after Sars-CoV-2 infection were common. Almost all the studies of Long COVID-19 reported on the persistence of fatigue, breathlessness and muscle weakness up to 3 months after initial symptoms. Furthermore, studies that sort to evaluate exercise impairment were consistent in demonstrating significant impairment in close to 30 % of COVID-19 survivors. There appears to be a consensus that cardiorespiratory compromise from the direct effects of the Sars-Cov-2 infection alone cannot explain the dominant symptoms of fatigue and breathlessness and that deconditioning probably plays an important role. Further research needs to focus on the extent to which deconditioning affects exercise capacity compared to the direct effects of the infection of the cardiorespiratory and musculoskeletal systems. Furthermore, research is needed to determine the longer-term impacts of COVID-19 infection beyond 6 to 12 months in miners where silicosis and tuberculosis levels are higher than in the general population. Finally, there is a need for research on whether pre-existing silico-tuberculosis is a risk factor for the development of Long COVID-19.

C) STUDY HYPOTHESIS

Reduced functional capacity and workability in miners post SARS-CoV-2 infection is present among those with Long COVID-19 and associated with certain comorbid factors.

D) STUDY JUSTIFICATION AND PURPOSE

Due to the novelty of COVID-19, there exists a large gap in the literature regarding Long COVID-19, its pathophysiology and natural history. The limited data currently available is mostly reported from studies done on patients in high-income countries and non-mining workers. The extent to which extrapolations can be made in order to use this data for miners in low-to-middle-income countries/regions remains unknown.

To our knowledge, no study has been done to evaluate the effect of COVID-19 on functional impairment and return to work in miners post COVID-19 and specifically with Long COVID-19.

The purpose of this research was to assist workplaces in formulating return-to-work policies for employees that have recovered from COVID-19 infection. By establishing the factors associated with reduced physical (exercise) tolerance, employers may design policies that identify which employees may return to strenuous intensely physical work, the frequency that they need to be monitored and what measures need to be put in place to ensure their health and safety and consequently their productivity.

E) STUDY AIM

To investigate the determinants of functional capacity and work ability in miners following COVID-19 disease.

F) OBJECTIVES

1. To determine the baseline demographic and medical characteristics of mineworkers in a ferro-manganese mine, prior to SARS-CoV-2 infection.

2. To identify the socio-demographic and occupational factors (age, gender, educational level, location of work, length of service, job category, vaccination status, tobacco use, ethanol use, body mass index) associated with COVID-19 in mineworkers.
3. To determine the functional capacity and workability using the Two Minute Walk Test (TMWT), the Post COVID-19 Functional Scale (PCFS) and the Work Ability index (WAI) questionnaire at baseline or immediately post-isolation and 3, 6 and 12 months after SARS-CoV-2 infection.

G) METHODS

Study design

This is a Cross-sectional study targeting all mine workers (> 18 years of age) who have been infected and diagnosed with SARS-CoV-2 working in a ferromanganese mine in Postmasburg in the Northern Cape province of South Africa.

Study population and design

The ferromanganese mine employs approximately 5000 employees including contractors. By the 30th of April 2022, a total of 1663 employees had tested positive since the start of the COVID-19 pandemic, while 733 cases from the total positive pool had been diagnosed in 2021 alone. The mine established a new sub-department (COVID hub) in the occupational health department to deal with all COVID -19 related matters including testing, contact tracing, post isolation, fitness assessment and complications management.

This was a cross-sectional study of miners who have had COVID-19 over a one-year period with a sample size of 204. Participation in the study was voluntary and based on informed consent (Appendix 2).

Sampling strategy and sample size

Participants were identified from the mine COVID-19 statistics and were invited to participate in the study. The selection of participants was based on the time since the onset of symptoms. All participants must have been diagnosed with COVID-19 within a 12-month period. Only employees aged 18 years and above who are manual labourers will be recruited. Employees in sedentary occupations such as office jobs were not included.

To date the following numbers of miners are diagnosed:

Timeline (as of January 2022)	Number of miners diagnosed with COVID-19
October – December 2021 (0 – 3 months)	196
July – September 2021 (4 – 6 months)	350
January – June 2021 (6 – 12 months)	360
June – December 202 (12 months plus)	690
January – April 2022 (12 months plus)	67

Data collection

1. ***Subjective health assessment and work ability***

Participants completed a questionnaire containing sociodemographic and medical characteristics, the Post COVID-19 Functional Status Scale (PCFS), and the Work Ability Index (WAI). The components were administered by a trained interviewer in English. The time allocated for each interview was approximately 40 minutes.

1.1 Sociodemographic Questionnaire

Each participant was asked questions (Appendix 3) regarding the demographic details (age, sex, marital status, education level, living circumstances); occupational details (occupation, department, length of service), habits (smoking, exercise frequency, substance abuse); and their medical history (TB, silicosis, asthma, COVID-19 details, HIV, hypertension, diabetes).

1.2. Post COVID-19 Functional Scale (PCFS)

Klok et al[22] proposed the use of an ordinal scale adapted from an earlier version that had been used to assess patients' functionality post venous thromboembolism (VTE) termed the PVFS (Appendix 4). Although the PCFS has not been validated and the value of its use does depend on the local conditions under which it is implemented, it was useful in complementing other tools to measure outcomes as has been used in other studies.

The clinician has the option of either using a series of questions structured in the flow chart format or a self-administered questionnaire in which the subject chooses the appropriate response in order to grade their own limitations. The gradings are as follows:

Grade 0 – No functional limitations
Grade 1 – Negligible functional limitations
Grade 2 – Slight functional limitation

Grade 3 – Moderate functional limitation

Grade 4 – Severe Functional limitation

1.3. Work Ability Index (WAI)

The WAI (Appendix 5) is a validated tool that has been used in occupational health research to assess work ability during workplace surveys[23]. It has been shown to be effective in predicting work disability, retirement and mortality and has been used widely in studies from different countries and translated into 24 languages. Its validity and reliability have been assessed and have been found to be reliable in predicting work disability, retirement and mortality.

The WAI covers 7 aspects related to current occupation and abilities post recovery from a medical condition. In this case, the condition of interest is SARS-CoV-2 infection. The questions prompt the subject to respond based on a grade on a given number scale. The questions cover workability, comorbidities, impairment, sick leave, prognosis and mental resources

The sum total of the score is then used to grade workability from poor to excellent, in which the lowest score represents poor workability and the highest score excellent workability. The grading system further gives recommendations on appropriate corrective actions.

2. ***Objective health assessment and functional ability***

2.1 *Anthropometric assessment*

The participants height and weight were measured and recorded in order to compute the Body Mass Index BMI (using the formula: BMI = eight/(height)^2).

2.2 Chest radiograph

Since yearly chest radiographs are mandatory for miners, the participants' latest pre-COVID chest radiograph was compared to a single chest radiograph within 12 months post-COVID-19.

Posterior-Anterior views of participants were taken and analyzed for new changes when compared with pre-COVID-19 radiographs using a standardized form (Appendix 6).

2.2 **Exercise Tolerance Test – The Two Minute Walk Test (TMWT)**.

The Two Minute Walk Test (TMWT) (Appendix 7) is a suitable test for functional endurance that has been validated in a variety of settings. Bohanon et al[24] were able to demonstrate its reliability and responsiveness in a meta-analysis study in 2017. They looked at four studies and produced normative values based on those studies. In the TMWT, the participant is asked to walk and cover as much ground as possible in a timed period of 2 minutes. The distance covered is then measured using a measuring wheel. Other tools commonly used in COVID-19 research include the 6-minute and 12 minute walk tests. Butland et al[25], and Connelly et al[26] showed that the 2MWT performance measurements were reliable and were correlated with subject performances on the 6MWT.

The criteria for discontinuing the test included: Abnormal pre-TMWT oxygen saturation levels <90%; chest pain which does not resolve at rest, dyspnoea precluding continuation of walking, contractures of lower limb muscles, balance disorders, severe sweating, pallor or cyanosis. Resuscitation readiness was ensured to enable a timeous response in case of complications during the test. The TMWT data collection sheet is attached in Appendix 7. Before and post the walk test, oxygen levels were recorded.

H) DATA MANAGEMENT AND ANALYSIS

I. Outcome variables

Key outcome variables include the presence of symptoms at any stage post-COVID-19, functional limitation as assessed by the PCFS with grading above 0, and abnormal scores on both the TMWT and WAI. Abnormal chest radiograph was classified based on the comparison with the latest Pre-COVID-19 radiograph to determine the presence of new changes associated with COVID-19.

II. Independent variables

These include the age of the participant, BMI, sex, vaccine status, number of episodes of SARS-CoV-2 infection, Pre-COVID-19 health status, the severity of acute SARS-CoV-2 infection and comorbidities present.

III Data Analysis

Data collected through questionnaires was stored in a password-protected excel spreadsheet. Results of the clinical assessment were also stored in the same format on a password-protected computer. Statistical analysis was done through the STATA 16 program (StataCorp, College Station, Texas, USA) obtained from the University of Cape Town. Counts (n) and proportions (%), means with standard deviations and medians with interquartile range (IQR) were used to present descriptive statistics depending on the type and distribution of data. To investigate associations, logistic regressions was used and presented as odds ratios (OR) with 95% confidence intervals (CI).

I) ETHICS

Ethics approval was sought from the University of Cape Town Health Sciences Faculty Research Ethics Committee (HREC) and the study was conducted based on the following ethical principles:

Autonomy

Voluntary enrolment with signed informed consent (Appendix 1 and 2) prior to participation was followed. The participant could withdraw at any point in time during the course of the study. The study was done at no cost to the participant or to the mine. The information sheet and consent form are contained in Appendix 1.

Confidentiality

Participants' personal information was be published in the research data and strict access to participant information was ensured through the use of passwords to laptops containing anonymized patient information. Confidentiality of the research site/employer information was also protected as the researcher has signed an agreement committing to not mentioning the name of the mine in the research findings (Appendix 8).

Benefit

Research findings revealed the cardiorespiratory fitness status post-COVID-19 of each participant who were referred for further management where appropriate. This aided in identifying rehabilitation needs for the participants and assist in accommodation in the workplace to allow for complete recovery and financial compensation

No harm

The only anticipated source of discomfort may have been the TMWT in Long COVID-19 sufferers that may have had dyspnea, fatigue or chest pain. Care was taken not to risk vulnerable individuals' health and safety through vigorous exercise and to have the necessary equipment and personnel on standby to assist in the event of a collapse or exacerbation of symptoms. The physical assessment testing was supervised by a medical doctor with both advanced cardiac life support training and advanced trauma life support training. Prior screening of all participants for effort intolerance was done through a brief history taking in vital signs was done and assessments of participants with a positive history of effort intolerance was postponed until the abnormality has been corrected. The assessment took place in an allocated area in close proximity to a casualty unit with full resuscitation capability.

Justice

Employees and organized labour and employers require a summary group report as will be produced in this research to inform return to work assessment policies and fair labour practices to ensure health and safety in the workplace and productivity. The novelty of COVID-19 means that there is still scanty information especially about long-term effects of COVID-19 which justifies this study.

J) RESEARCH FINDINGS AND DISSEMINATION OF RESULTS

Oral briefings for the workforce was also conducted to introduce the study and provide feedback on the results. Progress reports and a draft final report was provided to the company management and the union. An MPhil Occupational Health dissertation was based on this study and the study will be published in a scientific journal and submitted to the Minerals Council of South Africa to inform future policies in mining. The Human Rights Foundation was provided with feedback regarding the study findings given their sponsorship of the study.

K) PILOTING, LOGISTICS AND FUNDING

Following ethics, approval data collection began after initial piloting until March 2023. The study utilized occupational health resources such as photocopy machines and facilities hence no extra funding is necessary. The only cost is the tuition fees at the University of Cape Town which have been paid through funding from the human rights foundation.

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APPENDIX 11: IINSTRUCTIONS FOR AUTHORS FROM THE TARGET JOURNAL

OCCUPATIONALhealth
SOUTHERN AFRICA

Manuscript template

Use Arial font, size 11, and 1.5 line spacing.

TITLE
Type the title in bold, upper- and lower-case letters.

AUTHOR NAMES
Type the name(s) of the author(s) in bold, upper- and lower-case letters; state initials and surname; separate names with commas; and include affiliation reference numbers in superscript, e.g. A Author[1], B Author[2].

State affiliations, including location; and use superscript numbers, e.g. [1]North-West University, Potchefstroom, South Africa.

Indicate which authors, if any, belong to these Societies: SASOM, SASOHN, SAIOH, or MMPA.

CORRESPONDENCE
Type the corresponding author's name in Italics; and include his/her title, full names, postal address, and e-mail address.
e.g. Dr Andrew Author, address. e-mail: aauthor@...

ABSTRACT
Structure this as follows (300 words max.):
• ***Background:*** 2–3 sentences
• ***Objectives:*** 1–2 sentences
• ***Methods:*** include study design, study population, sampling method, data collection tools, statistical analysis
• ***Results:*** main findings – include important numbers and level of significance, if relevant
• ***Conclusion:*** 2–3 sentences; must be related to the objectives and findings of the study

Provide 4–5 **keywords**, using words that do not appear in the title.

INTRODUCTION
Begin with a brief overview of pertinent literature that is related to the study; and end with the main aim(s)/purpose or objective(s) of the study.

METHODS
Describe the study design, study population, sampling method, data collection (tools and methods), and data management (exposure and outcome variables), and state in detail the analytical or statistical methods used.

Provide a statement on the study ethics, including the name of the institution and the clearance certificate number allocated.

RESULTS
This section includes:
• Number of study participants or records, response rate, descriptive results (including socio-demographics of participants), tables and figures
• References to all tables, figures, etc. in the text
• Findings (state these but do not interpret the results)
• Tables (numbered from Table 1): all columns to be separate (n and % should be in separate columns); write the title above each table (e.g. Table 1. Description of the study population)
• Figures (numbered from Figure 1): must be clear, high quality and editable. Graph axes must be visible and labelled. Write the title below the figure (e.g. Figure 1. Prevalence of noise-induced hearing loss in construction workers, 2000–2014)
• Photographs: must be high resolution; include titles/caption of photograph and name of photographer below the photograph

DISCUSSION
Discuss the main findings – interpret the results of the current study and compare these with previous studies. Then state the study limitations – any factors (e.g. potential biases) that might influence the interpretation of the results. End by making recommendations, based on the study findings.

CONCLUSION

Write 4–5 sentences, related to the aim(s), purpose or objective(s) of the study, as stated in the Introduction.

KEY MESSAGES

Provide 3–5 (numbered) key messages that emanate from the study.

ACKNOWLEDGEMENTS

All those acknowledged must have provided permission to be mentioned in this section.

DECLARATION

Use the standard wording below, unless there are any conflicts of interest:
The authors declare that this is their own work; all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

AUTHOR CONTRIBUTIONS

State the author contributions as per below (add initials of relevant authors for each component):

- Conception and design of the study
- Data acquisition
- Data analysis
- Interpretation of the data
- Drafting of the paper
- Critical revision of the paper

REFERENCES

- Provide a maximum of 30 references.
- Use Vancouver style (papers will be rejected if the references are not written according to this style).
- See http://njirm.pbworks.com/f/vancouv.pdf or http://osirjournal.net/old/upload/files/2013/VANCOUVER_Reference_guide.pdf for guidance.
- Journal articles: state first six authors, followed by 'et al.'; abbreviate all journal titles (see: https://www.ncbi.nlm.nih.gov/nlmcatalog/journals); leave space after 'year'; and provide full start and end page numbers, e.g.
  Dembe AE, Erickson JB, Delbos RG, Banks SM. The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. Occup Environ Med. 2005; 62(9):588-597.

APPENDIX 11: Cover page for journal manuscript.

Determinants of functional capacity and work ability post SARS-CoV-2 infection in miners

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