Shift cycles and fatigue in the South African mining industry

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Shift work and fatigue are health and safety risks in industry. The aim of this research was to assess contributors to fatigue of workers in the South African mining industry (SAMI), including shift cycles, commuting times and lifestyle factors. This paper summarises past and current research conducted by the Council for Scientific and Industrial Research (CSIR) on the topic. The research employed mixed methods, as both qualitative and quantitative data were collected. Numerous factors were associated with fatigue, including work, demographic characteristics, socioeconomic and living conditions, and lifestyle factors. Current research conducted at the Mandela Mining Precinct (MMP) involves the development of a framework for optimising shift cycles in the SAMI, which will consider aspects such as travelling times, working conditions, fatigue and productivity. A holistic approach to shift scheduling, and fatigue management, should be applied to improve worker health, safety and wellbeing, and industry sustainability.

INTRODUCTION

Fatigue is a health and safety risk, and contributes to accidents, injuries and fatalities in the mining industry (Schutte, 2010; Theron, 2014). Fatigue results in impaired performance, productivity, alertness, motivation and mood, increases the risk of error, and can lead to health problems, including mental illness, and increased use of sick leave (Åkerstedt et al., 2014; Bates 2009; Pfeifer, 2017; Schutte, 2010; South Africa, 2014; Theron, 2014). Shift cycle arrangements, job demands and conditions, commuting times, and individual and lifestyle factors all contribute to fatigue (Schutte, 2010; South Africa, 2014). Shift work is required in mining and many other industries, and refers to "an organisation of work where workers succeed each other at the same workplace while performing similar operations at different times of the day thus allowing longer hours of operation than feasible for a single worker" (South Africa, 2014, p. 36). Shift work has negative effects on social and domestic activities, and can lead to occupational incidents and long-term physical or psychological health impairments, including cardiovascular disease and diabetes (Baulk et al., 2009; Härmä et al., 2018). Numerous factors are associated with accident and fatigue risk during shift work, including night or early morning work, backward-rotating shifts, extended shift lengths, excessive overtime, inadequate shift breaks and high job demands (Härmä et al., 2018; South Africa, 2014; Spencer et al., 2006; Theron, 2014).

The mining industry is a significant contributor to employment and the economy in South Africa but faces sustainability challenges, including increased operational costs, decreased production, and health, safety, environmental and social issues (Chamber of Mines of South Africa, 2018; Singh, 2017). South African narrow-reef hard-rock underground mines are deepening, and distances to the work faces are increasing, which result in increased travelling times to and from the workplace, shorter time available at the rock face ('face times'), increased health and safety challenges, reduced production, and increasing costs (Minerals Council South Africa, 2018; Rupprecht, 2018a). Activities undertaken during the mining cycle, such as safety meetings and re-entry examinations, further shorten the available face times (Rupprecht, 2018a). As a result, the traditional shift lengths of 8 hours and 20 minutes might not support a daily conformant blast (Rupprecht, 2018a; 2018b). For the purpose of this research, a conformant blast was defined as a blast which conformed to the minimum standards of a particular mine, while assessing parameters such as safety, face advances, fragmentation, and rock removal. The effects of long commutes between home and work are also not well understood (Gumbie, 2018). Further research has been recommended to assess the total time taken from when a mine worker leaves home for work until returning home afterwards, and to better understand the impacts of the work cycle on workers (Gumbie, 2018; Rupprecht, 2018b).

Not enough research has focused on the associations between demographic characteristics and socioeconomic conditions, including commuting times, and fatigue. Further research on the impact of current conditions in the South African mining industry (SAMI), on shift cycles and fatigue, is also warranted. Better understanding of this will assist mining companies to select the most appropriate shift cycles in terms of health, safety and productivity.

The aim of the research summarised in this paper was to assess the effects of factors including shift cycles, commuting times and lifestyle factors, on fatigue in workers in the SAMI.

This work draws on research conducted by the Council for Scientific and Industrial Research (CSIR) over the past five years. Findings related to shift cycles and fatigue from four research projects are described. The findings from three of the studies have been published in scientific peer-reviewed journals (Pelders and Nelson, 2019a; 2019b; 2019c), and were included in a PhD thesis at the University of the Witwatersrand. The fourth study is ongoing and is being conducted as part of the Longevity of Current Mines (LoCM) programme of the South African Mining Extraction Research, Development and Innovation (SAMERDI) strategy at the Mandela Mining Precinct (MMP).

METHODS

The studies were cross-sectional and used mixed methods – both quantitative and qualitative data were collected from questionnaires, semi-structured interviews and focus group discussions. The research took place across 12 mines and one platinum smelter in South Africa. Participants were selected, using purposive and convenience sampling, and included management and labour representatives, and workers. The interviews and focus groups were audio-recoded, and the qualitative data were transcribed and then analysed using thematic analysis. The quantitative data from the questionnaires were analysed using basic and inferential statistics, at a 95% significance level. The results were verified using methodological triangulation. Research assistants, fluent in local languages, translated information and assisted workers to complete the questionnaires, where required.

The research was approved by the CSIR Research Ethics Committee (reference numbers: 85/2013 and 239/2017) and the University of the Witwatersrand Human Research Ethics Committee (clearance certificate number: M140222).

RESULTS

Study 1: Socioeconomic contributors to health and safety of mine workers in South Africa

The Mine Health and Safety Council (MHSC) commissioned a project titled 'Health and safety impacts of socioeconomic conditions and other matters relating to living conditions in the South African mining industry' (project number: SIM 13-09-01) (Hodgskiss et al., 2015). Data collection for this project took place in 2014 at three platinum, two gold, one coal, one diamond and one manganese mine in South Africa. Data were collected from interviews and focus group discussions with mine workers (n=120), labour representatives (n=18) and individuals in mine management (n=67), and from questionnaires completed by mine workers (n=875). Fatigue was identified as a safety-related concern, and the related data were further assessed, and described in a paper accepted for publication in *Work* (Pelders and Nelson, 2019c).

From the interviews and focus group discussions, it was ascertained that fatigue resulted from various factors, including physical job demands, harsh working conditions, long working hours, shift configurations, and long commuting times. Additional aspects associated with fatigue were poor health, the use of medication, inadequate nutrition, alcohol use or abuse, insufficient sleep, poor sleeping conditions, and psychological problems. Data from the questionnaires revealed that 16% of the participating mine workers usually felt 'very sleepy' at work. As shown in Table 1, higher subjective fatigue was statistically significantly associated with lower incomes, living in hostel accommodation or informal housing, lack of exercise, fewer hours of sleep, and poorer quality of life.

Table 1. Statistically significant associations of sociodemographic characteristics with fatigue – Study 1.*

Variable	Category	Number of participants	% participants	Fatigue (% yes)	Fatigue (% no)
Average monthly income	≤ R 5 000	247	29	24	76
	R 5 001 – R 7 500	256	30	17	83
	R 7 501 – R 10 000	139	16	12	88
	> R 10 000	212	25	10	90
House type	Formal brick dwelling	317	39	10	90
	Flat/townhouse/cottage	100	12	18	82
	Hostel	126	15	24	76
	Shack/informal housing	116	14	20	80
	Backroom	161	20	18	82
Sleep received	< 6 hours	449	52	23	77
	≥ 6 hours	409	48	9	91
Exercise	Never	393	46	21	79
	Once a week or less	237	28	11	89
	More than once a week	229	27	14	86
Quality of life	Good	432	51	8	92
	Not good	421	49	24	76

*Chi-square tests performed ($p<0.05$)

Study 2: Contributors to fatigue at a platinum smelter in South Africa

The CSIR conducted fatigue-related research at a platinum smelter in South Africa in 2016. Selected data from this research were analysed and the findings regarding the associations between demographic characteristics, work, living and socioeconomic conditions, and lifestyle characteristics, and fatigue were published in the March 2019 edition of T*he Journal of the South African Institute for Mining and Metallurgy (SAIMM)* (Pelders and Nelson, 2019a).

Qualitative and quantitative data were collected from eight interviews with management representatives, two focus groups discussions with workers (n=24), and 75 questionnaires completed by workers.

Causes of fatigue mentioned during the interviews and focus group discussions included shift work, overtime, and work that was monotonous, repetitive or required high levels of concentration. Household responsibilities and social activities outside of working hours were also perceived to contribute to fatigue. Additionally, fatigue was perceived to be associated with age, sleep and stress. Data from the questionnaires showed that factors statistically associated with higher self-reported fatigue included younger age (≤35 years), renting or paying for housing, unhealthy diet, sleep disorders, higher stress, and lower job satisfaction (Table 2). More than half of the participants (52%) admitted to having unintentionally fallen asleep at work in the previous year, and 21% were usually 'moderately tired' to 'completely exhausted' when at work.

Table 2. Statistically significant associations of sociodemographic characteristics with fatigue – Study 2.*

Variable	Category	Number of participants	% participants	Fatigue (% yes)	Fatigue (% no)
Age	≤35 years	36	51	58	42
	>35 years	34	49	29	71
Housing tenure	Owned and paid off	6	9	17	83
	Owned by not yet paid off	25	36	40	60
	Rented	33	48	58	42
	Occupied rent-free	5	7	0	100
Healthiness of diet	Healthy	56	77	38	63
	Not healthy	17	23	65	35
Sleep disorder	Yes	11	16	73	27
	No	58	84	36	64
Stress	None/a little	48	68	27	73
	High	23	32	78	22
Job satisfaction	Good	39	55	67	33
	Not good	32	45	16	84

*Chi-square and Fisher's exact tests performed ($p<0.05$)

Study 3: Contributors to fatigue of mine workers in the South African gold and platinum sector
Further research relating to fatigue of mine workers was conducted by the CSIR in 2017 at four gold mines and one platinum mine in South Africa. The findings have been published in *Safety and Health at Work* (Pelders and Nelson, 2019b). Data were collected from 21 focus groups with individuals in mine management (n=48), union representatives (n=23), and mine workers (n=83), and questionnaires completed by 564 mine workers.

Table 3. Statistically significant associations of sociodemographic characteristics with fatigue – Study 3.*

Variable	Category	Number of participants	% participants	Fatigue (% yes)	Fatigue (% no)
Age	<40 years	286	60	32	68
	≥40 years	191	40	21	78
Debt	Yes	293	61	32	68
	No	191	39	22	78
Exercise	Yes	247	50	22	78
	No	243	50	33	67
Alcohol use	Once a month or less	365	74	25	75
	More than once a month	126	26	35	65
Diet	Health	350	72	24	76
	Not healthy	139	28	38	62
Sleep time before work	<6 hours	218	45	37	63
	≥6 hours	265	55	19	81
Sleep problems	Yes	120	26	44	56
	No	347	74	22	78
Health	Good	411	84	24	76
	Not good	81	16	43	57
Sick leave	<5 days	348	71	25	75
	≥5 days	141	29	34	66
Job satisfaction	Satisfied	254	52	21	79
	Not satisfied	239	48	34	66
Stress	Low	309	63	20	80
	High	181	37	40	60

*Chi-square tests performed ($p<0.05$)

Participants in the interviews and focus group discussions attributed fatigue to extended working hours, harsh working conditions, high job demands, and resource constraints. Aspects relating to demographic characteristics, socioeconomic and living conditions, lifestyle, health and wellness, were also associated with fatigue. Information collected from the questionnaires showed that higher fatigue was significantly associated with younger age, being in debt, a lack of recreational exercise, unhealthy diet, increased alcohol consumption, and a lack of sleep. Furthermore, higher levels of fatigue were associated with poor self-rated health, increase in sick leave taken, higher levels of stress, and lower job satisfaction (Table 3). Close to half of the participants (45%) usually received less than six hours of sleep before a work shift, and 14% usually felt more than 'a little tired' at work.

Current study: Development of a framework to optimise shift cycles in the SAMI

Current research commissioned by SAMERDI's LoCM programme aims to develop a framework to optimise shift cycles in the SAMI, while considering factors including productivity and fatigue. The need for this research was identified by the programme in 2017 and 2018 (Gumbie, 2018; Rupprecht, 2018b), in which key issues that constrain conventional narrow-reef underground gold and platinum group metals (PGM) mines from meeting their productivity and occupational health and safety (OHS) targets were identified. Both technical and people-centred issues were identified as constraints to zero harm production. Conventional mines are still highly labour-intensive, and are highly dependent on people to deliver on productivity, quality and OHS targets. Thus, the mines are vulnerable to negative people-centred issues such as non-conformance with mine standards and lack of a high-performance work culture. On the technical side, bottlenecks were identified in mining cycle activities, such as cleaning, support, drilling and blasting. The aforementioned inefficiencies are worsened by the limited available face time, which is no longer adequate for various production-related tasks to be completed, as a significant part of the shift time is consumed by travelling to and from the work place, and by completing other OHS obligations. The mines are getting deeper and mining activities have progressed further from the shafts, which has resulted in serious challenges in logistics (transportation of man,

material and ore) and the management of OHS. To this end, a study was commissioned to develop a framework to optimise shift cycles for OHS and productivity in South African underground narrow-reef hard-rock underground mines.

Numerous off-mine and in-mine considerations need to be made when designing shift cycles. Off-mine considerations include social and economic factors such as living conditions, family responsibilities, and worker commuting times to and from work, which have an impact on fatigue, and the physical and mental well-being of the workforce. In-mine factors include prevailing mine environmental conditions (temperature, humidity, air quality etc.), travelling times within the mine, and ancillary activities that impact on available face times in underground work environments. Other factors such as maintenance, logistics, availability of resources, quality of supervision, work-life balance, absenteeism and workplace culture, should also be considered when designing shift cycles. The resulting framework is envisaged to assist the mining industry to use a holistic approach to develop appropriate shift cycles. Changing shift cycles at any workplace is a fundamental change, requiring a proper change management process. Some key elements of a structured change management process include management and workforce buy-in, commitment and support, mitigation of potential adoption constraints, adequate communication, engagements and feedback with all the stakeholders.

DISCUSSION

Fatigue is a health and safety challenge in the SAMI, and the findings from the three completed studies showed that many workers experience high levels of fatigue at work. It is evident that fatigue is associated with numerous factors, including work-related factors, demographic characteristics, socioeconomic and living conditions, lifestyle, health, safety and wellness. The focus of the research was on sociodemographic contributors to fatigue, as this was identified as a research gap. However, during the course of the research, numerous work-related contributors to fatigue were identified. These contributors included extended working hours, overtime, shift configurations, labour-intensive work, work that was monotonous, repetitive, or required high levels of concentration, production pressure, a lack of resources, and harsh working conditions, including heat and humidity in underground workplaces, and those requiring long travelling distances. Similar findings relating to shift work and fatigue in the SAMI have been reported in literature (Härmä et al., 2018; South Africa, 2014; Spencer et al., 2006; Theron, 2014). Fatigue was more prevalent in younger workers, which could be a consequence of a lack of experience, participating in age-related social activities, or because workers that are least able to cope with the job demands may not stay for long (or grow older) in the job (the 'healthy worker effect').

Fatigue was also associated with socioeconomic and living conditions, and lifestyle factors. These factors included lower incomes and indebtedness, paying for accommodation, not living in formal houses, poor nutrition, lack of recreational exercise, increased alcohol use, insufficient sleep and sleep problems. Workers with financial problems might work extended hours in order to receive bonus or overtime pay, which could cause fatigue. Financial problems were also a major reported cause of stress which, in turn, was a primary cause of sleeplessness, leading to fatigue. Housing and sleeping conditions, including noise, exposure to adverse weather, and limited access to services and amenities are also likely to result in fatigue as they impact on health, and the amount and quality of sleep received. Lifestyle factors such as diet, exercise and alcohol use, might be causes or effects of fatigue. Longer commuting times to and from work were also suggested as contributors to fatigue: long commutes reduce the amount of time available to attend to household responsibilities and to sleep (Pfeifer, 2017).

Fatigue was also associated with higher stress, lower job satisfaction, lower quality of life, increased use of sick leave and poorer self-rated health. These findings support and bolster those reported in the literature, which have highlighted impacts of fatigue on absenteeism, and impaired OHS and wellness (Åkerstedt et al., 2014; Baulk et al., 2009; Härmä et al., 2018; South Africa, 2014).

Research currently underway at the MMP focuses on the development of a framework to optimise shift

cycles in the SAMI, to maximise productivity, while minimizing worker fatigue. Numerous factors need to be considered when assessing shift cycles, including worker commuting times and ancillary activities that impact face times in underground work environments. Impacts of shift cycles on workers include health, safety and social factors. Factors such as maintenance, logistics, stope heat and humidity, resources, supervision, absenteeism and workplace culture should also be considered. The resulting framework intends to provide industry stakeholders with a holistic approach to ascertain the most appropriate shift cycles for each operation. Related change processes and stakeholder engagements should also be carefully managed.

Limitations

The use of purposive and convenience sampling can result in bias, and the findings might not fully represent the SAMI. However, participants from a range of workplaces and job positions were selected to improve the generalisability of the findings. The use of self-report data can be a limitation as differences in understanding, personality and mood can affect responses. The complexity of fatigue and its measurement is also a challenge but validated tools were used to measure fatigue to minimise this bias. The cross-sectional nature of the studies prevented the assessment of cause and effect of fatigue, but data from the interviews and focus group discussions provided insight into reasons for associations between the different variables and fatigue. We believe that, despite the limitations, the findings from this research provide valuable information about, and insight into fatigue in the mining industry.

CONCLUSION

Numerous factors including work-time arrangements, job demands, work conditions, and demographic-, socioeconomic-, living condition-, or lifestyle-related factors can contribute to fatigue. Fatigue management and shift schedule arrangements in the South African mining sector need to be holistically assessed to ensure optimal productivity and to minimize health and safety risks. Changing shift cycles would require a structured change management process for successful implementation. Reduced fatigue and optimal shift scheduling will contribute to the sustainability of the mining industry.

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