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Original Article

Contributors to Fatigue of Mine Workers in the South African Gold and Platinum Sector

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ABSTRACT

Background: Mine workers in South Africa face challenges relating to poor health and safety, including fatigue risks, and poor socioeconomic and living conditions. Fatigue results in impaired mental and physical performance. The aim of this study was to assess contributors to fatigue of mine workers in South Africa.

Methods: Data collection took place at four gold mines and one platinum mine in South Africa. A total of 21 focus groups were held with individuals in management, union representatives, and mine workers, and 564 questionnaires were completed by mine workers to gather information about fatigue and potential contributors to fatigue at these mines.

Results: Qualitatively (through focus groups), fatigue was attributed to extended working hours, harsh working conditions, high workloads, production pressure, and resource constraints, along with aspects relating to demographic and socioeconomic factors, living conditions, lifestyle, health, and wellness. Greater fatigue was significantly associated with younger age, indebtedness, a lack of exercise, poor nutrition, less sleep, increased alcohol use, poor self-reported health, more sick leave, higher stress, and lower job satisfaction.

Conclusion: The aim of the study was achieved; numerous work-, sociodemographic-, lifestyle-, and wellness-related factors were linked to fatigue in the participating mine workers. Contributors to fatigue should be addressed to improve health, safety, and sustainability in the industry.

1. Introduction

The South African mining industry (SAMI) is a significant contributor to the economy of the country but faces sustainability, occupational health, and safety challenges [1,2]. The SAMI is traditionally labor intensive and takes place in difficult conditions [3,4]. In addition, the SAMI has residual problems faced by mine workers, relating to historically poor socioeconomic conditions, substandard living conditions, racial discrimination, and poor health [5–8]. Mining companies are required to contribute to the improvement of living conditions of their workforces, community development, and transformation of the industry [8–13]. Furthermore, the SAMI is required to have a minimum participation of 10% of women in mining [9–11]. Mines are also required to develop a code of practice for any matter where health and safety could be affected by mining activities; this includes fatigue management [14].

Fatigue is defined as "a state of impaired mental and/or physical performance and lowered alertness, arising as a result or combination of hard physical and mental work, health and psychosocial factors, or inadequate restorative sleep" [15 p 145]. Fatigue is a causal or contributing factor to accidents and injuries in the mining industry [15]. Increased levels of fatigue lead to reduced levels of alertness, coordination, judgment, and motivation and impaired mood and job satisfaction [16–19]. Job satisfaction refers to perceptions or attitudes that people have toward their work [20]. Fatigue can also lead to long-term health problems such as digestive problems, heart disease, stress, and mental illness and is associated with increased use of sick leave [17,21]. Stress can be defined as an imbalance between the demands placed on an individual and the resources that the person has for coping with these demands [22].

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Causes of fatigue are multifactorial. Work-related causes include shift schedules, task requirements, and work and environmental conditions [14,21,23]. Individual and nonwork causes include differences with age, sex, education, poor diet, drug and alcohol use, inadequate sleep and rest, medical conditions, psychological issues such as stress, and demanding activities or commitments outside of work [16,19,21,23–26]. Socioeconomic conditions that potentially contribute to increased fatigue of mine workers include poor housing, overcrowding, and long commuting times, which can disrupt sleep and limit sleep time, and financial constraints to affording necessities such as decent food, housing, and basic services; socioeconomic and living conditions are also associated with psychosocial factors, lifestyle, and health [21,27,28].

There is a lack of research about the association between individual characteristics and fatigue; the influence of sociodemographic variables, other than sex and age, is largely unknown [23,24]. Further research on this topic would be beneficial to identify factors associated with fatigue and, in turn, use the findings toward improving health, safety, well-being, and productivity in the SAMI. The conceptual framework that was developed for this study, based on literature reviewed and a theoretical understanding of associations between the study variables, is displayed in Fig. 1. The model shows potential contributors to fatigue, along with associations between the variables. The aim of the study was to assess contributors to fatigue of workers at gold and platinum mines in South Africa. The results could be used to implement interventions to reduce fatigue-related risks.

2. Methods

2.1. Study setting and population

Data were collected from four gold mines and one platinum mine located in four of the nine provinces in South Africa in 2017. The total estimated workforce size at these mines was approximately 40 000, and the SAMI directly employed around 464 700 people at that time (personal communication, Department of Mineral Resources, 6 July 2016) [1]. The gold and platinum sectors employed the most people in the industry in South Africa, with 112 200 and 175 770 in the gold and platinum sectors, respectively [1]. The study population comprised individuals in management, union representatives, and mine workers at each of the five mines.

2.2. Sampling procedures

Those in management and union representatives were purposively selected based on their positions at the mines. Convenience sampling was used to select the participating mine workers because it was not possible to get a probabilistic sample. The mine workers were recruited from areas including the mine training centers, so that production would not be interrupted by removing workers from the workplace. Consequently, there could be bias in the findings, such as a lower percentage of fatigued participants than the entire study population. In addition, this sampling method prevents the scientific inference of the findings to the broader population of mine workers; it rather provides an exploratory understanding of the research topic. Workers from a range of job positions and shifts were selected from each mine to enhance the representability of the sample and included engineering and production personnel.

2.3. Data collection

This was a cross-sectional, mixed-methods study. Qualitative data were gathered from a total of 21 focus group discussions that were held with 154 individuals, including 48 managers, 23 union representatives, and 83 mine workers, across the five operations. In most cases, one focus group discussion was held with management, one with union representatives, and two with workers, at each mine. The focus group discussions were semistructured, and questions were posed to gain an understanding of perceptions of fatigue and potential contributors to fatigue of the mine workers. The focus group discussions were conducted in languages that were readily understandable by the participants and were voice-recorded.

Quantitative data were gathered using questionnaires. The questionnaires included forced-choice questions to gather information about worker demographics; living and socioeconomic conditions; and lifestyle, health and wellness, including sleepiness and fatigue. The independent variables (26 items) are listed in Table 1 and were measured using single-item measures. Previous authors have validated the use of single-item measures, including those for stress and job satisfaction [29–32]. Sleepiness and fatigue were measured using an adapted version of the Samn–Perelli fatigue scale [33], the Karolinska Sleepiness Scale (KSS) [34], an indication of having unintentionally fallen asleep at work in the

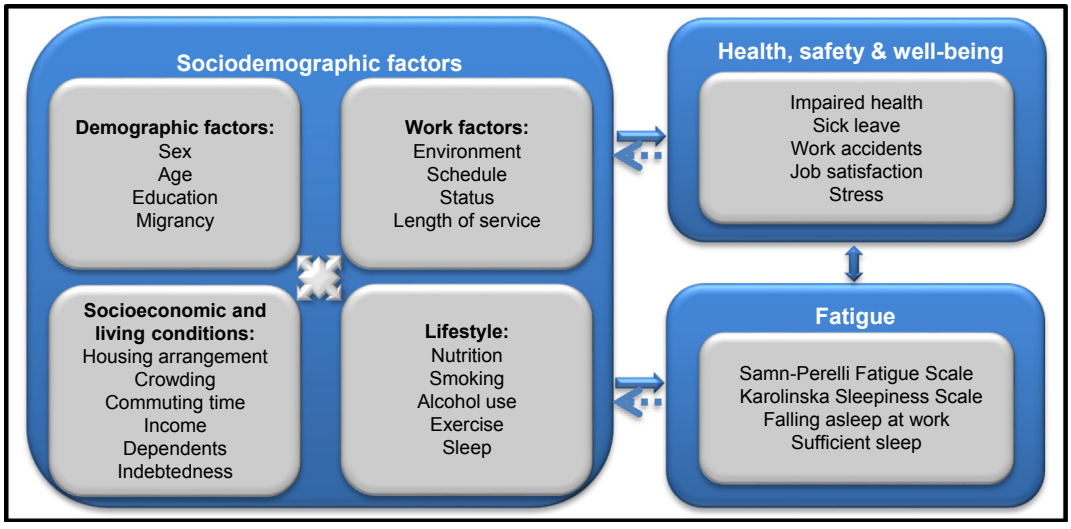

Fig. 1. Conceptual framework of the study.

Table 1
Participant characteristics and associations with fatigue* (n = 493)

Variable	Category	Participants	Fatigue		
		n (%)	Yes, n (%)	No, n (%)	*p*†
Sex	Male	431 (88)	117 (27)	314 (73)	0.370
	Female	58 (12)	19 (33)	39 (67)	
Age	<40 years	286 (60)	91 (32)	195 (68)	*0.013*
	≥40 years	191 (40)	41 (21)	150 (78)	
Education	<Grade 12	299 (61)	72 (24)	227 (76)	*0.034*
	≥Grade 12	192 (39)	63 (33)	129 (67)	
Province of origin	Same as mine province	142 (29)	48 (34)	94 (66)	0.054
	Different to mine province	349 (71)	88 (25)	261 (75)	
Country of origin	South Africa	385 (79)	118 (31)	267 (69)	*0.004*
	Other	104 (21)	17 (16)	87 (84)	
Work area	Surface	69 (14)	17 (25)	52 (75)	0.598
	Underground	408 (86)	113 (28)	295 (72)	
Night shifts	Yes	178 (37)	54 (30)	124 (70)	0.416
	No	305 (63)	82 (27)	223 (73)	
Work status	Permanent	369 (77)	109 (30)	260 (70)	0.247
	Contract	109 (23)	26 (24)	83 (76)	
Length of service	<5 years	223 (47)	70 (30)	163 (70)	0.248
	≥5 years	260 (53)	66 (25)	194 (74)	
Living out allowance	Yes	325 (68)	88 (27)	237 (73)	0.685
	No	156 (32)	45 (29)	111 (71)	
Number sharing room	1–2 people	250 (52)	73 (29)	177 (71)	0.429
	>2 people	231 (48)	60 (26)	171 (74)	
Commuting time	<30 minutes	327 (66)	90 (28)	237 (72)	0.965
	>30 minutes	166 (34)	46 (28)	120 (72)	
Salary	<R7500	314 (64)	95 (30)	219 (62)	0.099
	>R7500	176 (36)	41 (23)	135 (76)	
Dependents	<6	250 (51)	70 (28)	180 (72)	0.857
	≥6	242 (49)	66 (27)	176 (73)	
Debt	Yes	293 (61)	93 (32)	200 (68)	*0.019*
	No	191 (39)	42 (22)	149 (78)	
Exercise	Yes	247 (50)	55 (22)	192 (78)	*0.006*
	No	243 (50)	81 (33)	162 (67)	
Smoking	Yes	115 (24)	39 (34)	76 (66)	0.090
	No	372 (76)	96 (26)	276 (74)	
Alcohol use	Once a month or less	365 (74)	92 (25)	273 (75)	*0.036*
	More than once a month	126 (26)	44 (35)	82 (65)	
Diet	Healthy	350 (72)	83 (24)	267 (76)	*0.001*
	Not healthy	139 (28)	53 (38)	86 (62)	
Sleep time before work	<6 hours	218 (45)	81 (37)	137 (63)	*0.000*
	≥6 hours	265 (55)	51 (19)	214 (81)	
Sleep problems	Yes	120 (26)	53 (44)	67 (56)	*0.000*
	No	347 (74)	77 (22)	270 (78)	
Health	Good	411 (84)	100 (24)	311 (76)	*0.001*
	Not good	81 (16)	35 (43)	46 (57)	
Sick leave (previous year)	<5 days	348 (71)	86 (25)	262 (75)	*0.036*
	≥5 days	141 (29)	48 (34)	93 (66)	
Work accident (previous year)	Yes	64 (13)	23 (36)	41 (64)	0.086
	No	424 (87)	109 (26)	315 (74)	
Job satisfaction	Satisfied	254 (52)	54 (21)	200 (79)	*0.001*
	Not satisfied	239 (48)	82 (34)	157 (66)	
Stress	Low	309 (63)	62 (46)	247 (80)	*0.000*
	High	181 (37)	72 (54)	109 (60)	

* Results of Chi-squared analysis.
† Italics values indicate significance ($p < 0.05$).

previous year, and a self-report of receiving sufficient sleep or not. The Samn–Perelli scale required responses on a seven-point scale (1 = "fully alert, wide awake"; 7 = "completely exhausted, unable to function effectively"), whereas the KSS is a nine-point scale (1 = "extremely alert", 9 = "very sleepy, great effort to stay awake"). Researchers assisted the participants to complete the questionnaires, where necessary, to eliminate language and literacy barriers.

The questionnaires were completed by 564 mine workers, of which 432 worked at the four gold mines and 132 at the platinum mine. The average response rate to each of the questions was 98% (±2%), ranging from 91% to 100%. Most participants were male (88%); this reflected national mining employment statistics, as women represented 12% of the mining labor force in 2017 [1]. The average age was 38 (±9) years, ranging from 20 to 65 years. Further details of participant characteristics are shown in Table 1.

2.4. Data analysis

The focus group discussions were translated into English, where applicable, and transcribed, and data obtained from the questionnaires were captured into Microsoft Excel 2010. Thematic analysis was used to analyze the information gathered during the focus group discussions; the data were coded, and recurring themes were identified. For the quantitative data, descriptive and inferential statistics, including frequencies, percentages, means, standard deviations (indicated in parentheses following the ± sign), Chi-squared tests, and stepwise binary logistic regression, were performed using StataCorp's Stata 13.1 software at a significance level of $p < 0.05$. Data were grouped, where necessary. For the inferential analysis, a binary fatigue variable was created using a combination of variables. A positive fatigue rating was given if the participant scored positively for two or more of the following: (1) more than "a little tired" on the adapted version of the Samn–Perelli fatigue scale; (2) a score of six ("some signs of sleepiness") or more on the KSS; (3) having unintentionally fallen asleep at work in the previous year; and (4) not receiving enough sleep.

2.5. Ethical considerations

Ethical approval to conduct this research was received from the Council for Scientific and Industrial Research CSIR Research Ethics Committee (Reference No.: 85/2013) and the Human Research Ethics Committee of the University of the Witwatersrand (Certificate No.: M140444). Permission to conduct the study at each of the mines was also received. Voluntary informed consent was obtained from each of the participants. The data gathered in the study remain confidential.

3. Results

3.1. Perceptions of the mine workers, labor representatives, and management

3.1.1. Fatigue

Perceptions of fatigue frequently mentioned in the focus group discussions are described in this section. The participants generally agreed that fatigue was a challenge across all job categories. Mental and physical fatigue was seen to lead to impaired concentration, work performance, decision-making, and motivation, along with an increased likelihood of falling asleep at work, accidents, injuries, fatalities, damage to equipment, and absenteeism. A manager commented:

> *"It (fatigue) affects all our employees, because of the working environment that we are in. Remember, mining is very risky and dangerous. Therefore… it will definitely have an impact on their performance, and then it could also affect the health and safety of the employees underground. Consequently it will also lead to production loss."*

Fatigue was attributed to various factors, including the working hours, work conditions, and workload. The potential influences of demographic and socioeconomic factors, living conditions, commuting times, lifestyle, and health or wellness were also discussed.

3.1.2. Work

Extended working hours were the most frequently reported cause of fatigue. Workers often did not have enough time to get sufficient sleep as a result of the working hours and were often required to work hours longer than official shift times to complete the required work. Reported causes of extended working hours included production pressure, the bonus system, overtime work, inadequate staffing levels, delays in receiving materials, equipment and infrastructure constraints, or breakdowns. The early start times of morning shifts, night shifts, and circadian disruptions when working rotating shifts were further potential causes of fatigue. Most of the workers were required to work on weekdays and alternate Saturdays, but a number commented that they would prefer not to work on Saturdays to have enough time to attend to family responsibilities and to rest.

Production workers received bonuses when achieving certain targets and requirements. A participant said, *"The issue of bonuses is killing us. They shouldn't pressure us to work by using the bonus system. People want money, so even if they are fatigued they would still work in order to get extra money".*

Overtime was worked on days off to complete work that could not be done during the work week or by workers, including artisans, who were on standby and responded to calls to attend to breakdowns outside of normal working hours. Some worked overtime on weekends to receive more pay. It was noted that workers with specialized skills sometimes worked excessive overtime because no one was available to replace them at work. Participants observed:

> *"You also get fatigue from long hours per day, but you can get fatigue working normal hours but never having an off Saturday or off Sunday because you work overtime on those days. So it can happen that you work for two weeks and have no day off in between."*

> *"It's the same with guy that works his morning shift, then there comes during the day or at the end of the shift a breakdown, then he must stay on until that breakdown has been rectified… it can take up to 23 to 24 hours that that guy stays underground. So definitely when he comes up from underground he's fatigued, his body is wasted."*

The work environment, job demands, and workplace culture contributed to fatigue as a result of harsh conditions, strenuous work, and production pressure associated with mining. High temperatures, humidity, dust, and long traveling distances underground were commonly mentioned. Workers often had to walk long distances to get to their workplaces once inside the mines. Physical job demands, high workloads, a lack of breaks, and monotonous work were further mentioned risks. Participants commented, *"The heat is killing us. It makes us to always be tired"* and *"The distance that we walk to our working areas is too long. We get tired before we can even start working".*

Equipment, material, and infrastructure constraints were additional concerns. Overcrowding and delays of mine conveyors when entering or leaving the mines and a lack of transportation to underground workplaces were noted. A lack of equipment, delays in the delivery of materials, and a breakdown or insufficiency in services, such as compressed air, water, or electricity, also resulted in workers having to work longer hours than scheduled to meet the day's production targets.

Inadequate staffing levels were a further contributor to fatigue. Reduced staffing resulted in higher workloads for the remaining team members and was a particular challenge when some were on leave or were absent. Participants said, *"There's too much work and too little people"* and *"They must provide enough labour if they want to control fatigue"*. Workers often complained about not being able to take leave when it was due or requested because no one was available to relieve them at work, which precluded the opportunity for rest and recovery. Conversely, absenteeism and the abuse of sick leave were seen to result from fatigue. A participant admitted, *"We end up being absent from work because of fatigue. Sometimes even accidents occur due to being too tired at work. There are always complaints that we are always absent from work, but they can't realise that we are fatigued?"* However, other workers came to work even when sick or dangerously fatigued to still qualify for a bonus or because they were afraid of being accused of abusing sick leave.

3.1.3. Demographics

The demographic characteristics of workers, including sex, age, education, migrancy, and work status, were discussed in terms of their potential associations with fatigue. More women were entering the mining industry, but women were acknowledged to be less physically strong than men, which could result in higher levels of fatigue of the work team as the men helped the women to complete tasks that they could not do. A female participant stated, *"… really it's impossible to work the same as the men. You can try, but you can't perform like they are doing".* In addition, pregnancies were seen to lead to increased strain in the work team as women were not allowed to work underground while pregnant or breastfeeding, and their positions were not filled by others.

In terms of age and education, it was generally noted that the older workers, being more experienced and skilled, tended to work harder and be stronger than the younger workers, who tended to be more educated than the older workers. The older workers, therefore, could be more resilient to fatigue. Some of the participating mines had a relatively high percentage of migrant labor from neighboring countries or from remote regions in South Africa; however, this percentage was decreasing, and the proportion was lower among younger workers. Migrant workers generally did not live with their families while working at the mines. Although fatigue was not generally perceived to differ between migrant and local workers, traveling times when going to rural homes could be a fatigue risk for migrant workers. For example, a participant commented:

> *"Like me, I'm from Mozambique. Let's say I have an emergency at home that I need to attend to and request three to four days off. It takes about two days for me to get home. When I get there I'll attend to what I have to do and return back to work. By the time I get back it's late already so I just leave my bag and go straight to work. I'll be very tired but I won't have a choice but to work".*

Additional financial and social stressors could be placed on migrant workers, for example, as a result of living apart from families or having second families at the mines or because of additional household responsibilities, such as cooking or cleaning, if not living with a partner that attended to these responsibilities.

3.1.4. Socioeconomic and living conditions

Socioeconomic and living conditions were also perceived to contribute to fatigue. Income was associated with fatigue for reasons that included working excessive hours for overtime or bonus pay to supplement earnings. Participants commented, *"The salary we get is too little so we are trying to add (to) it with working overtime"* and *"People are working harder to earn better".* Financial problems and debt were noted and were further associated with stress and sleeplessness. Contract workers were perceived to generally receive lower pay and benefits, but to work harder, than permanent employees.

Mine workers lived in a range of housing types, including formal brick houses, mine hostels, backrooms, and shacks. Mine employees usually received a living-out allowance if living outside of

the mine-funded property. Fatigue could result from disturbed sleep if living in a noisy environment or if sharing a room. A worker mentioned:

> *"It's a challenge sometimes because we work different shifts. Sometimes you'll be trying to sleep during the day because you will be going for a night shift, and the one who is already back from his shift will be making noise or busy with other stuff while you are trying to sleep."*

Poor living conditions, such as exposure to elements, crime, and a lack of amenities, were considered to contribute to poor health and fatigue. Furthermore, traveling distances and commuting time to work and home from work affected the time workers had to sleep. A worker commented, *"Some of us have to wake up at two in the morning so that you can be able reach work in time…So by the time you get to work you are tired already..."* Workers used a range of modes of transport, including taxis, buses, staff transport, cars, walking, and hitchhiking to get to work.

3.1.5. Lifestyle

Lifestyle-related factors, including activities performed outside of work, and nutrition were associated with fatigue. Workers often found it difficult to attend to family responsibilities and to rest adequately outside of work because of lack of time. Participants said, *"When you get home the kids also need attention – assistance with homework, you need to do the house chores… So we are forever tired"* and *"You don't have family time or anything. You're working in for Christmas, you're working in for Easter – you're working overtime"*. Females potentially had more household responsibilities than men because of traditional roles. A lack of recreational exercise was perceived to result from a lack of time, energy, and adequate facilities. Alcohol abuse was a reported problem that could lead to fatigue and was attributed to stress and a lack of recreational facilities. Eating unhealthy or convenience foods and irregular meal times were noted, which could result in poor health and fatigue. In addition, some workers did not eat at work because of the poor conditions and a lack of time. The rationing of food allowed underground, to prevent food being sold to illegal miners, was another concern as some mentioned that these rations were not sufficient to maintain energy levels throughout the shift.

3.1.6. Health, safety, and well-being

Health and wellness were associated with fatigue. Health problems and the use of medication could lead to drowsiness and fatigue, and conversely, fatigue could lead to poor health, psychological strain, and injuries. Examples of health problems that were mentioned were high blood pressure, diabetes, HIV/AIDS, tuberculosis, respiratory problems, sinus problems, headaches, and flu. Stress was another common concern and was considered to lead to lack of focus, absenteeism, and accidents at work, along with sleeplessness and fatigue. Participants noted, *"If you are stressed too much you can't sleep"* and *"So most of the time, your mind doesn't have the time to rest – you are always thinking. It can also cause fatigue"*. The main reported causes of stress were financial problems and indebtedness, whereas other causes were family problems, poor living conditions, transport challenges, and work-related stressors, such as working conditions, high workloads, long working hours, production pressure, and job insecurity.

3.1.7. Recommendations

Participants made recommendations to reduce fatigue and improve fatigue management at the mines. These included improved work planning and scheduling, such as reassessing the shift schedules; improved monitoring and evaluation of hours worked and leave taken; better staffing; improved infrastructure and supply of necessary equipment and materials; and revision of the current bonus system. Improved health and wellness programs, better recreational facilities, revision of the food rations allowed underground, and the provision of easily accessible midshift sustenance were recommended. Assistance with better housing and transport was also suggested. The need for improved communication between stakeholders at the mines was also highlighted, along with the need to prioritize health and safety, rather than production.

3.2. Results of data gathered using questionnaires completed by mine workers

Results of the fatigue indicators recorded in the questionnaires were as follows: (1) On the adapted Samn–Perelli fatigue scale, 14% indicated usually feeling more than "a little tired" at work; (2) more than a quarter (27%) reported usually feeling some level of sleepiness in the past year, as indicated by a score of over five on the KSS; (3) almost a quarter (24%) reported unintentionally falling asleep at work in the past year; and (4) a total of 39% did not think that they received enough sleep. A binary fatigue score was calculated based on positive responses to two or more of the four indicators, and 28% of the sample population was classified as fatigued. This score was not calculated for participants who omitted any of the four questions, which resulted in a sample size of 493 for the Chi-squared tests.

The results for the Chi-squared tests for associations between participant characteristics and fatigue are shown in Table 1. A number of variables were significantly associated with the summary fatigue score. Interestingly, younger age, higher level of education, and being a local South African worker were associated with a higher prevalence of fatigue. Those who were in debt reported being more fatigued. A lack of exercise, higher levels of alcohol use, and unhealthy diets were also statistically associated with increased fatigue. As expected, those who usually slept for fewer than six hours in the 24 hours before a work shift and those with sleeping problems were more likely to be fatigued than those who slept for more hours and had better quality sleep. Lower levels of fatigue were associated with good self-rated health, fewer than five days of sick leave taken in the previous year, higher levels of job satisfaction, and lower stress levels.

Stepwise binary logistic regression was used to assess the relationship between multiple predictor variables and fatigue. All the variables were included in the initial regression model. The criteria for inclusion of the variables into the final model were set at $p < 0.20$. A stopping criterion between 0.15 and 0.20 is recommended, with the best criteria increasing with the number of predictor variables [35]. Of the 26 predictor variables, 10 were included in the final model. Stress was the largest contributor to fatigue. Those with high levels of stress were 2.75 times more likely to be fatigued than those with low levels of stress after controlling for the variables of hours of sleep usually received before work, sleep problems, being a local versus a migrant worker, income, self-reported health, age, exercise, and work area (Table 2).

4. Discussion

The results from the questionnaires and focus group discussions were triangulated to better understand contributors to fatigue of the participating mine workers. The quantitative associations were explained by the qualitative data; these findings are discussed in the following part of the article and are compared to literature on the topic. In addition, although the focus of the study was to address the lack of knowledge about sociodemographic contributors to fatigue, information gathered in the focus group discussions

Table 2
Associations of multiple predictor variables and fatigue*

Variable (category)	Odds ratio	95% confidence interval		p†
Stress (high)	2.75	1.62	4.68	*0.000*
Sleep time before work (≥6 hours)	0.39	0.23	0.67	*0.001*
Country of origin (South Africa)	2.52	1.14	5.52	*0.021*
Sleep problems (yes)	2.05	1.16	3.62	*0.013*
Salary (>R7500)	0.50	0.28	0.89	*0.018*
Health (good)	0.58	0.30	1.13	0.112
Age (≥40 years)	0.56	0.32	0.99	*0.045*
Exercise (yes)	0.60	0.35	1.02	0.061
Province of origin (same as mine province)	1.59	0.89	2.84	0.117
Work area (underground)	1.67	0.79	3.52	0.182

CI, confidence interval.
* Results of stepwise logistic regression.
† Italics values indicate significance ($p < 0.05$).

provided insight into the context of the study by highlighting work-related contributors to fatigue.

In general, the findings of this study supported previous research that has found that fatigue can lead to reduced concentration or alertness, work performance, and motivation and increased health and safety risks [15–18].

The results from the Chi-squared tests showed that lower age, higher levels of education, and being local to the country were associated with higher levels of fatigue, which were unexpected. However, previous studies have found mixed results. Some studies have linked older age and a lack of education to higher levels of fatigue, whereas other studies found that fatigue was associated with younger age and that there was no association between education and fatigue [19,21,23,36]. Di Milia et al [23] did note, however, that workers with higher socioeconomic status, which is related to educational level, could be more at risk of mental fatigue than workers with lower socioeconomic status. It was expected that the migrant workers would experience more fatigue than local workers because of factors such as long traveling distances, healthcare disruptions, and social and financial strain [37]. The Chi-square associations could be explained by the qualitative data, however, as the participants mentioned that the older workers, which included a higher proportion of migrant workers, tended to be able to handle job demands better than the younger, more educated workers. This finding also supports the "healthy migrant hypothesis," which indicates that migrants are positively selected into the workforce based on health and explains the findings of previous research, indicating that migrants are generally healthier than those from the areas to where they migrate [38,39].

A number of significant associations between lifestyle-related variables and fatigue were evident. First, a lack of recreational exercise was associated with fatigue. As mentioned in the focus groups discussions, it is possible that those who were fatigued did not have the time or energy to participate in exercise outside of work because of the long working hours, high job demands, and harsh working environment. Conversely, a lack of recreational exercise could lead to impaired health and mental well-being, which may further be associated with fatigue. Second, those who considered their diets to be healthy reported lower levels of fatigue. Poor nutrition was a noted contributor to fatigue and a lack of energy in the focus group discussions. Poor nutritional intake was also attributed to long and irregular working hours and a lack of time to prepare food and to eat. Third, fatigue was further associated with higher levels of alcohol intake. Increased alcohol use could be a cause of fatigue or a consequence of fatigue and mental strain. Participants in the focus groups also attributed alcohol abuse to stress and a lack of alternate recreational facilities. The findings that those who usually had less than six hours of sleep before a work day and those with sleep problems experienced higher levels of fatigue were expected [23]. The focus group participants commonly attributed fatigue to a lack of time to get adequate sleep—particularly because of extended working hours—and to sleep disturbances such as stress or worry and noise. Consistent with the findings from the focus group discussions, a number of authors have indicated that social activities or commitments, along with long work hours, can compete with rest and recovery [40–42].

Health-related and well-being–related variables were associated with fatigue. Lower levels of fatigue were reported by participants who considered their health to be good. The association between health and fatigue was expected as fatigue can result from poor health and disease [18,19,21]. Fatigue and circadian disruptions have also been identified as causes of health problems [17,23]. The focus group participants similarly noted that poor health could lead to, or result from, fatigue. Similarly, higher amounts of sick leave taken were associated with higher levels of fatigue; this could result from the associations with poor health. In addition, the focus group participants noted fatigue to be a cause of absenteeism from work or the "abuse" of sick leave. Åkerstedt et al [21] and Åkerstedt [43] also reported that fatigue is seen to lead to sick leave and the use of health facilities.

Higher fatigue could have been a cause or consequence of lower job satisfaction and higher stress in the participants. Halvani et al [19] found that fatigue was significantly associated with job satisfaction. In addition, fatigue and disturbed sleep have been associated with psychological disorders including depression and burnout and higher levels of stress [18,21,43,44]. Results from the logistic regression analysis indicated that stress was the variable that best explained fatigue in the participants. The focus group participants indicated that stress was a cause of sleeplessness and fatigue. A common cause of stress was financial problems, which could be a reason for the association between indebtedness and fatigue. Participants also worked excessive hours to receive bonus or overtime pay, which could result in fatigue.

Significant associations were not found between a number of the other measured variables and fatigue in the Chi-squared test results. For example, sex was not significantly associated with fatigue. More than 10% of the participants were female, which reflects the Mining Charter requirements for participation of women in mining. Some participants believed that females could experience higher levels of fatigue as a result of generally lower physical work capacities and additional household responsibilities, whereas some asserted that males experienced higher levels of fatigue as they assisted to complete the work tasks that women could not. Heavier workloads could also be experienced by the entire work team when women were absent from work while pregnant or breastfeeding. Previous literature indicates that females are generally at a higher risk of fatigue than males [23]. Significant associations between housing arrangements, overcrowding, commuting time, number of dependents, and fatigue were also not evident. Meanwhile, in the focus groups, the participants identified reasons why poor living conditions, overcrowding, long commuting times, and low salaries could lead to fatigue. Fatigue results from the combined influence of living and working environments [42].

It was surprising that work-related factors, including work area, working night shifts, work status, and length of service, were not statistically associated with fatigue. This is because the long working hours, high job demands, and work environment were noted to be major causes of fatigue by the focus group participants and in previous research [14,21,23,42]. However, fatigue was considered to affect workers across all job categories, and

it is likely that participants from each category confronted different potential contributors to fatigue. For example, those who were not required to work night shifts were more likely to be required to be on standby and work more overtime. Finally, although fatigue is a known contributor to work accidents, it was not significantly associated with having been involved in an accident at work in the previous year. It is likely that there are additional contributors to accidents at work.

4.1. Limitations

The study made use of self-reported data, and as such, findings could have been influenced by aspects including personality and mood. Although many variables were considered, other unmeasured variables might contribute to fatigue. The index used to define fatigue in this study, while incorporating previously validated scales, may be limited to certain aspects of the multifaceted concept of fatigue, and there may have been differences in understanding by participants in the current context. In addition, while associations between variables were determined, the cross-sectional nature of the study precluded the analysis of cause and effect. A further limitation is the sampling method used because probabilistic sampling could not be performed for this study. Notwithstanding these limitations, the study provides insight into challenges faced by mine workers in South Africa and factors associated with fatigue in the study sample, and it contributes to the body of knowledge about sociodemographic contributors to fatigue. Further research is recommended to validate the exploratory findings of this study. Future studies could include the objective measurement of fatigue and longitudinal analyses of mine workers' fatigue.

4.2. Conclusion and recommendations

This study contributed knowledge relating to the aim of the study, which was to assess contributors to fatigue of gold and platinum mine workers in South Africa. Furthermore, the findings supported the conceptual framework that was developed from literature on the topic. Fatigue is a risk to health, safety, well-being, and productivity of mine workers in South Africa. Extended working hours were the main reported cause of fatigue identified by the participants, but fatigue was also associated with sociodemographic, lifestyle, health, and wellness characteristics. Higher levels of fatigue were associated with getting fewer hours of sleep, sleep problems, indebtedness, a lack of exercise, increased alcohol use, unhealthy diets, poor health, increased sick leave taken, reduced job satisfaction, and high levels of stress. Those with high stress levels were almost three times more likely to be fatigued than those with low levels of stress. It was surprising that lower levels of fatigue were associated with older ages, lower levels of education, and not being local to South Africa. Addressing challenges of fatigue and the many variables associated with fatigue, including stress, would result in improved health, safety, and sustainability in the SAMI. A change in the workplace culture is required to ensure safe production and to avoid risks associated with production pressure. Improved employee wellness programs are also recommended.

Conflict of interest

There is no conflict of interest to declare.

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