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Contributors to fatigue at a platinum smelter in South Africa

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Synopsis

Fatigue is a significant concern in the mining industry as it is a causal or contributing factor in many incidents and accidents. Fatigue can be caused by work- and non-work-related factors. There is a lack of information about associations between demographic and other non-work factors, and fatigue. This study aimed to assess associations between demographic, work, living, and socioeconomic conditions, and lifestyle characteristics, and fatigue at a platinum smelter in South Africa. Eight interviews with management and two focus groups with production workers were conducted, and 75 questionnaires were completed by production and other workers. Both work- and non-work-related factors were considered to be causes of fatigue. These factors included overtime, shift work, high workloads, activities performed outside of work, age, race, housing tenure, diet, sleep disorders, stress, and job satisfaction. In general, higher levels of fatigue were reported by younger participants, those who rented accommodation, ate less healthily, had a sleep disorder, and those with high levels of stress and low job satisfaction. As various demographic, lifestyle, and wellness-related factors were associated with fatigue, both work and non-work contributors should be addressed in fatigue management plans.

Keywords
Sleepiness, living conditions, lifestyle, fatigue management, mining industry.

Background

Fatigue may be defined as 'a state of impaired mental and/or physical performance and lowered alertness arising as a result of, or a combination of, hard physical and mental work, health and psychosocial factors or inadequate restorative sleep' (BHP Billiton, 2005). Williamson *et al.* (2011) define fatigue as a biological drive for recuperative rest. Sleepiness and fatigue are related, and the terms are often used interchangeably. However, sleepiness, more specifically, can be defined as sleep propensity, or a person's tendency to fall asleep (Hossain *et al.*, 2003; Shen, Barbera, and Shapiro, 2006).

Increasing levels of fatigue and sleepiness are associated with lapses in attention, errors, response slowing, fluctuations in alertness and effort, and impaired attention, working memory, long-term memory, decision-making, and creativity (Alhola and Polo-Kantola, 2007; van Dongen and Dinges, 2000). Fatigue is also associated with adverse effects on mood and impulsive behaviours (Alhola and Polo-Kantola, 2007; Minkel *et al.*, 2011; Schwarz *et al.*, 2013). It is a significant concern in the mining industry as it is commonly identified as a causal or contributing factor in many accidents and injuries (Schutte, 2009). Fatigue can also lead to long-term health problems, including digestive problems, heart disease, stress, and mental illness (Shaw, 2003).

Fatigue can be caused by both work-related and non-work-related factors. Work-related causes include work schedules and design, task requirements at work, and the work environment conditions. Work scheduling factors include the number and pattern of hours worked, time of day, shift work, and night work (Di Milia *et al.*, 2011; NSW, 2009; Schutte and Maldonado, 2003; Shaw, 2003). Task requirements associated with fatigue include high mental and physical demands, especially monotonous tasks or tasks requiring sustained attention (Åkerstedt *et al.*, 2014; Jing-Gang and Lei, 2013; NSW, 2009; Schutte and Maldonado, 2003; Shaw, 2003; Williamson *et al.*, 2011). Work environment factors include noise, temperature extremes, or the psychosocial environment (Jing-Gang and Lei, 2013; NSW, 2009; Shaw, 2003).

Individual and non-work contributors to fatigue include aspects such as sleep, health, fitness for work, lifestyle factors, and commuting time (Åkerstedt *et al.*, 2014; Di Milia *et al.*, 2011; Horrey *et al.*, 2011; NSW, 2009). Age, diet, drug and alcohol use, medical conditions, quality and quantity of rest before a work period, circadian rhythm ('body clock'), sleep disorders, strenuous activities outside of work (*e.g.* a second job), family commitments, and psychological issues such

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as stress also play a role in the levels of fatigue experienced (Åkerstedt *et al.*, 2014; Molarius *et al.*, 2006; ORR, 2012; Schutte and Maldonado, 2003; Shaw, 2003). In addition, living conditions are likely to influence the levels of fatigue experienced by mineworkers due to poor conditions in which to sleep, long commuting times between work and home, and poor health arising from a lack of access to services and amenities (Åkerstedt *et al.*, 2014; Galobardes *et al.*, 2006).

Horrey *et al.* (2011) reported that many demographic, personality, and workplace factors can impact the levels of fatigue experienced and their consequences. De Milia *et al.* (2011) noted that the interaction between demographic factors and fatigue is a neglected area of research and that, apart from age and sex, the influence of many demographic factors is largely unknown. There is a lack of information about associations between demographics, living conditions, and various other non-work factors and fatigue (Di Milia *et al.*, 2011; Horrey *et al.*, 2011). Living and socioeconomic conditions have been highlighted as a particular concern in the South African mining industry. Further study on these factors is warranted to assist in broadening the understanding of their effects on fatigue so that they might be considered in fatigue management programmes in order to implement appropriate interventions. The aim of this study was to assess associations between demographic, work, living and socioeconomic conditions, and lifestyle characteristics, and fatigue in the South African Mining Industry.

Methodology

The study design was cross-sectional. Although most data collected was quantitative, qualitative data was also gathered, and methodological triangulation was used to verify the results. Participants were recruited from a platinum smelter located in Limpopo Province in South Africa, in 2016.

Semi-structured interviews were held with eight individuals in management positions or their representatives. These individuals were selected based on their positions at the smelter, namely those from human resources, finance, health and safety, laboratory, production, engineering, and protection services. Two focus group discussions were held with groups of 11 (9 male and 2 female) and 13 (7 male and 6 female) production workers, respectively. Convenience sampling was used to select these participants. The interview and focus group participants were asked about fatigue experienced at the smelter and its potential causes, both at work and outside of work, and were requested to make recommendations for reducing it. The interviews and focus group discussions were held in the language most readily understood by the participants which, in this case, was English. The interviews and discussions were voice-recorded.

Quantitative data was collected using questionnaires that were completed by workers employed at the smelter. Participants were selected using convenience sampling. The smelter employed 188 permanent employees in the workgroups included in the study, and around one-third of these were sampled. The study focused on production workers, such as those working at the furnace, as it was assumed that they would be at a high risk of fatigue and its effects. However, other groups of workers, such as those working in engineering departments and in laboratories, were also included.

Closed-ended questions were used to gather information about participant demographics, work, living and socioeconomic conditions, lifestyles, health and wellness, and fatigue. Four questions were used to assess levels of fatigue, namely (1) whether participants thought they received enough sleep, (2) general sleepiness using the Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990), (3) a subjective rating of fatigue at work, adapted from the Samn-Perelli fatigue scale (Samn and Perelli, 1982), and (4) whether the participant had unintentionally fallen asleep at work in the past 12 months. For the KSS, participants were asked to rate how sleepy they generally felt on a scale from 1 ('extremely alert') to 9 ('very sleepy, great effort to stay awake'). Subjective fatigue at work was recorded on a five-point Likert scale from 'fully alert, wide awake', to 'completely exhausted.' The participants completed the questionnaires under the guidance of researchers who were fluent in local languages.

Data from the voice recordings was downloaded and transcribed. Thematic content analysis was used to summarize responses from the interviews and focus groups. Data from the questionnaires was captured electronically using Excel software. A binomial fatigue variable was created using data from the four questions in the questionnaire that were designed to assess fatigue. If data from two or more of these questions indicated high levels of fatigue (*i.e.* not receiving enough sleep, a KSS score of over 5, a fatigue rating of more than 'a little tired', and/or falling asleep at work unintentionally in the past year), a positive fatigue score was indicated for the participant. In addition to descriptive analyses, Pearson chi-squared and Fischer's exact tests were conducted using Stata 13 software to determine whether there were significant associations between each of the demographic, work, living and socioeconomic condition, and lifestyle variables, and the summary fatigue variable. To improve the integrity of the inferential statistics, data was grouped or omitted, where appropriate, to increase the number of responses per category. Fisher's exact test was used in cases where the number of participants per cell was less than five. Statistical significance was set at 95% ($p < 0.05$).

Ethical approval to conduct this study was obtained prior to data collection from the CSIR Research Ethics Committee (reference number: 158/2015) and the University of the Witwatersrand Human Research Ethics Committee (certificate number: M140222). Necessary permission to conduct the study was obtained from the company.

Results

Perception of fatigue by management and production workers

Participants in the interviews and focus groups generally felt that fatigue was a problem at the smelter, especially for those working in hazardous occupations. However, it was considered to be relatively well managed. Those in management identified various work-related causes of fatigue, including overtime, shift work, repetitive and monotonous work, and work that required high levels of concentration. Overtime work was a particular concern for engineering personnel as they worked on 'standby' in

addition to working normal day shifts. Production and laboratory workers, on the other hand, worked 12 hour shifts that included night shift work. The production workers noted short staffing, including that resulting from absenteeism, as the main concern relating to fatigue, as this led to increased workloads.

Activities outside of work were also considered to contribute to fatigue by both those in management positions and the production workers. These included family responsibilities, part-time studies, and social activities. Personal differences such as age, intrinsic sleeping rhythms, and stress were also linked to fatigue. The socioeconomic conditions (*e.g.* income, education, transport, and housing) of the smelter workers were seen to be relatively good, and the daily commuting times were not generally excessive; as such, these factors were not of particular concern for fatigue.

Levels of fatigue

A total of 75 questionnaires were completed. The average response rate to each of the questions was 98%, ranging from 95% to 97%.

Table I shows the demographic profile of the study participants. The majority of the participants were male (68.5%) and the average age was 37 (±7) years, with a range of 22–60 years. Most of the participants were Black Africans (87.7%). All were South African, and most (79.5%) came from Limpopo, the province where the smelter was located. The participants were relatively well educated: 56.9% had a post-Grade 12 qualification and only 5.6% had not completed secondary school.

Selected work-related variables are shown in Table II. The majority of the participants (53.4%) worked in the furnace section, 17.8% in the engineering department, 15.1% in the regional laboratory, and 13.7% in the process laboratory. Most (86.3%) were permanent employees, and 67.1% worked shifts. In general, those working in the furnace section and in the process laboratory worked shifts, while those in the engineering department and the regional laboratory did not. The shifts were 12 hours long, and included night shifts. About one-third (34.2%) of the participants reported that they often worked overtime.

Findings relating to the living and socioeconomic conditions of the sample are included in Table III. Access to services was relatively high, and most (97.2%) had electricity in their dwellings. Most of the participants lived within a 50 km radius of the smelter, and the majority (84.7%) had commuting times of less than 30 minutes. Most used their own vehicles to travel to and from work. The median number of people that relied on the participants' incomes was four. Over a quarter (27.4%) reported always or often finding it difficult to pay for all the things they needed, and 39.7% reported owing money to someone.

With regard to lifestyle, 32.9% reported exercising in their leisure time more than once a week, 15.7% smoked, and 41.1% drank alcohol more than once a month (Table IV). In terms of nutrition, 76.7% considered the food they ate to be healthy or very healthy; none reported it to be unhealthy or very unhealthy. Over a quarter of the participants (26.0%) reported usually having fewer than 6 hours of sleep in the 24 hours before a work shift; 27.4% slept for 6–7 hours, and 46.6% slept for 7 or more hours. These values compare to 11.1%, 16.7%, and 72.2%, respectively, prior to days off work. Participants also generally reported having better quality sleep before a day off work than before a work day.

Table V shows that 21.4% of the participants reported having a medical condition and 23.3% reported taking medication. Most (86.3%) considered their health to be good or very good, and 34.7% had not taken any sick leave in the previous year. While some of the participants were unsure if they had a sleep disorder or not, 15.9% reported having one. Around 4.2% of the sample reported having a work-related injury, and 2.8% had been involved in a work-related

Table I

Demographic characteristics and the associations with fatigue

Variable	Participants	Fatigue		p-value
	n (%)	Yes n (%)	No n (%)	
Sex				
Male	50 (68.5)	21 (42.0)	29 (58.0)	0.641 (P)
Female	23 (31.5)	11 (47.8)	12 (52.2)	
Age				
≤35 years	36 (51.4)	21 (58.3)	15 (41.7)	**0.015* (P)**
>35 years	34 (48.6)	10 (29.4)	24 (70.6)	
Race				
Black	64 (87.7)	32 (50.0)	32 (50.0)	**0.004* (F)**
Other	9 (12.3)	0 (0.0)	9 (100.0)	
Marital status				
Married	37 (50.7)	16 (43.2)	21 (56.8)	0.918 (P)
Not married	36 (49.3)	16 (44.4)	20 (55.6)	
Home province				
Limpopo	58 (79.5)	25 (43.1)	33 (56.9)	0.804 (P)
Elsewhere in South Africa	15 (20.5)	7 (46.7)	8 (53.3)	
Highest level of education				
Grade 12 or less	31 (43.1)	10 (32.3)	21 (67.7)	0.070 (P)
Higher than Grade 12	41 (56.9)	22 (53.7)	19 (46.3)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

Table II

Work variables and the associations with fatigue

Variable	Participants	Fatigue		Chi²
	n (%)	Yes n (%)	No n (%)	p-value
Work area				
Furnace	39 (53.4)	20 (51.3)	19 (48.7)	0.318 (F)
Process laboratory	10 (13.7)	5 (50.0)	5 (50.0)	
Regional laboratory	11 (15.1)	4 (36.4)	7 (63.6)	
Engineering	13 (17.8)	3 (23.1)	10 (76.9)	
Work status				
Permanent	63 (86.3)	29 (46.0)	34 (54.0)	0.497 (F)
Contract	10 (13.7)	3 (30.0)	7 (70.0)	
Shift work				
Yes	49 (67.1)	25 (51.0)	24 (49.0)	0.077 (P)
No	24 (32.9)	7 (29.2)	17 (70.8)	
Overtime				
Yes	25 (34.2)	12 (48.0)	13 (52.0)	0.605 (P)
No	48 (65.8)	20 (41.7)	28 (58.3)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

Table III

Living and socioeconomic condition variables and the associations with fatigue

Variable	Participants n (%)	Fatigue		Chi² p-value
		Yes n (%)	No n (%)	
Location of dwelling				
Mine (smelter) property	8 (11.3)	5 (62.5)	3 (37.5)	0.230 (F)
Suburban area	34 (47.9)	15 (44.1)	19 (55.9)	
Township	18 (25.3)	9 (50.0)	9 (50.0)	
Rural area	11 (15.5)	2 (18.2)	9 (81.8)	
Housing tenure status				
Owned and fully paid off	6 (8.7)	1 (16.7)	5 (83.3)	**0.037* (F)**
Owned but not yet paid off	25 (36.2)	10 (40.0)	15 (60.0)	
Rented	33 (47.8)	19 (57.6)	14 (42.4)	
Occupied rent-free	5 (7.3)	0 (0.0)	5 (100.0)	
Level of crowding (number in room)				
One	17 (23.6)	9 (52.9)	8 (47.1)	0.415 (P)
Two	40 (55.6)	15 (37.5)	25 (62.5)	
More than two	15 (20.8)	8 (53.3)	7 (46.7)	
Piped water in dwelling				
Yes	60 (87.0)	26 (43.3)	34 (56.7)	0.724 (F)
No	9 (13.0)	3 (33.3)	6 (66.7)	
Flush toilet				
Yes	64 (88.9)	31 (48.4)	33 (51.6)	0.068 (F)
No	8 (11.1)	1 (12.5)	7 (87.5)	
Commuting time				
Less than 15 minutes	9 (12.5)	3 (33.3)	6 (66.7)	0.598 (F)
15 to less than 30 minutes	52 (72.2)	25 (48.1)	27 (51.9)	
30 minutes to less than an hour	11 (15.3)	4 (36.4)	7 (63.6)	
Difficultly affording necessities				
Always/often	20 (27.4)	11 (55.0)	9 (45.0)	0.076 (P)
Sometimes	24 (32.9)	13 (54.2)	11 (45.8)	
Occasionally/never	29 (39.7)	8 (27.6)	21 (72.4)	
Indebtedness				
Yes	29 (39.7)	15 (51.7)	14 (48.3)	0.270 (P)
No	44 (60.3)	17 (38.6)	27 (61.4)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

Table IV

Lifestyle variables and the associations with fatigue

Variable	Participants n (%)	Fatigue		Chi² p-value
		Yes n (%)	No n (%)	
Exercise				
Once a week or less	49 (67.1)	24 (49.0)	25 (51.0)	0.206 (P)
More than once a week	24 (32.9)	8 (33.3)	16 (66.7)	
Smoke				
Yes	11 (15.7)	6 (54.5)	5 (45.5)	0.394 (P)
No	59 (84.3)	24 (40.7)	35 (59.3)	
Drink alcohol				
Less than once a month	43 (68.9)	15 (34.9)	28 (65.1)	0.065 (P)
More than once a month	30 (41.1)	17 (56.7)	13 (43.3)	
Healthiness of diet				
Healthy or very healthy	56 (76.7)	21 (37.5)	35 (62.5)	**0.048* (P)**
Neither healthy nor unhealthy	17 (23.3)	11 (64.7)	6 (35.3)	
Average hours of sleep – before work				
<7 hours	39 (53.4)	20 (51.3)	19 (48.7)	0.170 (P)
≥7 hours	34 (46.6)	12 (35.3)	22 (64.7)	
Average hours of sleep – before off-days				
<7 hours	20 (27.8)	8 (40.0)	12 (60.0)	0.745 (P)
≥7 hours	52 (72.2)	23 (44.2)	29(55.8)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

Table V

Health and wellness variables and the associations with fatigue

Variable	Participants	Fatigue		Chi²
	n (%)	Yes n (%)	No n (%)	p-value
Medical condition				
Yes	15 (21.4)	6 (40.0)	9 (60.0)	0.801 (P)
No	55 (78.6)	24 (43.6)	31 (56.4)	
Sleep disorder				
Yes	11 (15.9)	8 (72.7)	3 (27.3)	**0.024* (P)**
No	58 (84.1)	21 (36.2)	37 (63.8)	
Medication				
Yes	17 (23.3)	10 (58.8)	7 (41.2)	0.155 (P)
No	56 (76.7)	22 (39.3)	34 (60.7)	
Self-reported health				
Good or very good	63 (86.3)	27 (42.9)	36 (57.1)	0.740 (F)
Not good	10 (13.7)	5 (50.0)	5 (50.0)	
Sick leave in previous year				
0 days	25 (34.7)	8 (32.0)	17 (68.0)	
1–9 days	34 (47.2)	16 (47.1)	18 (52.9)	0.202 (P)
More than 10 days	13 (18.1)	8 (61.5)	5 (38.5)	
Stress				
Not at all / a little stressed	48 (67.6)	13 (27.1)	35 (72.9)	**0.000* (P)**
Very stressed	23 (32.4)	18 (78.3)	5 (21.7)	
Job satisfaction				
Not satisfied	39 (54.9)	26 (66.7)	13 (33.3)	**0.000* (F)**
Satisfied	32 (45.1)	5 (15.6)	27 (84.4)	
Quality of life				
Good	57 (79.2)	23 (40.4)	34 (59.7)	0.366 (P)
Not good	15 (20.8)	8 (53.3)	7 (46.7)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

Table VI

Fatigue ratings

Variable	Participants	Fatigue		Chi²
	n (%)	Yes n (%)	No n (%)	p-value
Enough sleep				
Yes	49 (67.1)	11 (22.5)	38 (77.6)	**0.000* (P)**
No	24 (32.9)	21 (87.5)	3 (12.5)	
KSS ratings of general sleepiness				
1 – 5: Not sleepy	38 (53.5)	8 (21.0)	30 (79.0)	**0.000* (P)**
6 – 9: Sleepy	33 (46.5)	24 (72.7)	9 (27.3)	
Fatigue rating – in general while at work				
Fully alert, wide awake	9 (12.7)	0 (0.0)	9 (100.0)	
Somewhat fresh, lively	18 (25.4)	5 (27.8)	13 (72.2)	
A little tired	29 (40.8)	11 (37.9)	18 (62.1)	**0.000* (F)**
Moderately or very tired	9 (12.7)	8 (88.9)	1 (11.1)	
Completely exhausted	6 (8.5)	6 (100.0)	0 (0.0)	
Fallen asleep unintentionally at work in past year				
Yes	38 (52.1)	30 (79.0)	8 (21.1)	**0.000* (F)**
No	35 (47.9)	2 (5.7)	33 (94.3)	
Summary fatigue variable				
Fatigued	32 (43.8%	32 (100.0)	0 (0.0)	N/A
Not fatigued	41 (56.2)	0 (0.0)	41 (100.0)	

*Indicates significance at $p < 0.05$. (P) Pearson's chi-square test performed. (F) Fisher's exact test performed.

accident in the previous 12 months. Almost half of the participants (45.1%) reported being satisfied with their jobs, 23.9% were neither satisfied nor dissatisfied, and 31.0% were dissatisfied. Most (79.2%) considered their quality of life to be good. One-third (32.4%) reported being very stressed.

A summary of the fatigue ratings of the participants can be found in Table VI. Two-thirds (67.1%) thought that they received enough sleep. The average level of sleepiness recorded in the KSS was 5 ('neither alert nor sleepy'); 46.5% reported some degree of sleepiness, as indicated by a score of 6 or higher. When the participants were asked to rate how

fatigued they usually felt while at work, 21.2% reported feeling moderately tired or completely exhausted. Over half (52.1%) reported having unintentionally fallen asleep while at work in the past year. From the summary variable based on the results for these four fatigue-related items, 43.8% of the participants were classified as fatigued. A summary variable could not be calculated for two participants, as a result of missing data, reducing the sample size for the chi-square and Fisher's exact tests to 73.

Associations with fatigue

Results of the Pearson chi-square and the Fisher's exact tests are shown in Tables I to VI, together with the percentage of participants in each category that were identified as fatigued. Both age and race were associated with fatigue ($p<0.05$, Table I). A higher proportion of those aged 35 years or younger reported to be fatigued than those older than 35. Black participants reported fatigue more frequently than those of other race groups. The proportion of participants that was not black was small, which could influence the validity of this result. Most of the non-black participants (89.9%) were over 35 years and only 22.2% of this group did shift work. No statistically significant associations with fatigue and sex, marital status, home province, or education were seen.

None of the recorded work-related variables were significantly associated with fatigue (Table II). However, some trends were evident, such as higher levels of fatigue in those working at the furnace and the process laboratory than in those working in the regional laboratory and the engineering department. Higher levels of fatigue were also reported by those that did shift work, those that worked overtime, and permanent employees, although the differences were not statistically significant.

Housing tenure was associated with fatigue ($p<0.05$, Table III). Those who owned and had fully paid off their homes and those who occupied dwellings rent-free reporting lower levels of fatigue than those who rented or owned but had not yet paid off their dwellings. Area of dwelling, level of crowding, access to piped water and flush toilets, commuting time, difficulty affording necessities, and indebtedness were not significantly associated with reported fatigue.

Those who considered their diets to be healthy or very healthy reported less fatigue ($p<0.05$), but exercise, alcohol use, smoking, and sleep received were not significantly associated with fatigue (Table IV).

Sleep disorders, stress, and job dissatisfaction were positively associated with fatigue ($p<0.05$) (Table V). Those reporting as having a sleep disorder, high stress levels, and poor job satisfaction reported higher levels of fatigue. Having a medical condition, taking medication, self-reported health conditions, sick leave, and quality of life were not statistically associated with the fatigue variable in this study. The four variables that were used to predict fatigue were significantly associated with the summary fatigue variable ($p<0.001$, Table VI).

Discussion

Fatigue was identified in 44% of the study participants, as indicated by subjective responses and reports of falling asleep unintentionally while at work. From the interviews and focus groups conducted, both work- and non-work-related factors contributed to fatigue. The factors that were significantly associated with fatigue were age, race, housing tenure status, healthiness of diet, sleep disorders, stress and job satisfaction.

The higher levels of fatigue reported by the younger workers could be a result of the 'healthy worker effect', as those that can best handle the work demands are most likely to remain in the job. It might also be a result of social activities that the younger participants are involved in outside of work. This was mentioned in the focus groups. Reasons for the non-black group reporting lower levels of fatigue could be because they were, on average, older than the black participants, and because a lower percentage of them did shift work. However, only nine (12.3%) of the participants were non-black, which could have biased the results.

It was unexpected that none of the work-related variables were significantly associated with fatigue. It was anticipated that factors such as working shifts and working overtime would be associated with higher levels of fatigue. However, it is noteworthy that the participant groups generally either worked shifts (*i.e.* production and laboratory workers) or commonly worked overtime (*e.g.* those in engineering). As such, it is possible that these factors counteracted the associations, as shift work and overtime would both affect fatigue in the different groups.

Those who rented accommodation or were paying housing debts reported higher levels of fatigue than those who lived rent-free or had paid off their housing. The latter group might be less stressed and under less pressure to work harder or longer hours to earn production bonuses. As the living conditions, commuting times, and socioeconomic conditions of the participants were generally not seen to be problematic, this could explain the lack of association of these factors with fatigue in this sample.

Those who considered their diets to be healthy reported lower levels of fatigue. Healthier diets might lead to better or more sustained energy levels. Reports of healthy eating might also be linked to personality or psychosocial states or traits, with those who are more optimistic reporting better health and lower fatigue.

As might be expected, those who reported having a sleeping disorder experienced higher levels of fatigue, likely due to inadequate restorative sleep. It was unexpected that hours of sleep obtained were not significantly associated with fatigue. This could point to the importance of sleep quality in relation to fatigue, including the ability to adapt to shift work, rather than sleep length alone. It could also be that the 7-hour cut-off used in the study as an indicator of insufficient sleep was too high.

Higher stress levels and poorer job satisfaction were both strongly associated with fatigue. Stress and job dissatisfaction could be either causes or consequences of fatigue. Workers might be stressed and dissatisfied because they are fatigued, or fatigue may result from high levels of stress and dissatisfaction (*e.g.* because of impaired sleep quality). Stress and fatigue have commonly been considered to be associated, and fatigue has been associated with impairments in mood (Åkerstedt *et al.*, 2014; Republic of South Africa, 2014; Shaw, 2003). Stress and job dissatisfaction have also been linked (*e.g.* Coomber and

Barriball, 2007). Extraneous variables, such as high workloads or challenging work conditions, might contribute to the experience of stress, job dissatisfaction, and fatigue, simultaneously. Although some research has shown fatigue to be associated with increased sick leave or absenteeism and poor health (*e.g.* Åkerstedt *et al.*, 2014), the current study failed to demonstrate these associations. Nevertheless, some trends were evident in the data, such as correlation of increased fatigue with increased sick leave, poorer subjective health, and poorer quality of life

A limitation of the study is the small sample size, which might have reduced the statistical significance of the findings. The use of convenience sampling was a further limitation, as it could result in sampling bias. The study participants might not have represented the workforce, being healthier and less fatigued workers, as they were not absent from work or on sick leave at the time of the study. Another limitation is that the study made use of self-reported data. Factors such as personality, mood, and understanding could have affected the responses. Furthermore, as the focus of the study was to gather more information about non-work contributors to fatigue, only basic data about work-related factors was gathered. The inclusion of more detailed work-related information, such as work design, scheduling, and environmental factors, would have allowed for a more complete understanding of contributors to fatigue at these operations. It should also be noted that as the study was conducted at a single workplace, the findings may not be generalizable. Notwithstanding these limitations, we believe that the results provide an indication of levels of fatigue and contributors to them.

Conclusion and recommendations

Several demographic, living condition, lifestyle, health, and wellness variables were associated with fatigue in this group of smelter workers. Generally, factors within the work environment receive most attention when it comes to fatigue management. It is recommended that mining workplaces also take factors outside of the workplace into consideration in their fatigue management programmes. Further study in different settings and with larger sample sizes would be worthwhile in order to confirm these findings, and to generate recommendations relating to non-work contributors to fatigue that can be applied more broadly.

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