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Title page

Barriers to occupational heat stress risk adaptation of mining workers in Ghana

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Barriers to occupational heat stress adaptation of mining workers in Ghana

Abstract

Increasing temperature and climate warming impacts are aggravating the vulnerability of workers to occupational heat stress. Adaptation and social protection strategies have become crucial to enhance workers' health, safety, productive capacity and social lives. However, the effective implementation of work-related heat stress adaptation mechanisms appears to be receiving little attention. This study assessed the barriers to occupational heat stress adaptation and social protection strategies of mining workers in Ghana. Based on a mixed methods approach, focus group discussions and questionnaires were used to elicit data from 320 mining workers. Workers' adaptation strategies (water intake, wearing loose and light-coloured clothing, participating in training programmes, taking regular breaks, use of mechanical equipment, use of cooling systems and housing designs) varied significantly across the type of mining activity ($p < 0.001$). Workers' social protection measures were adequate. The disparities in workers' social protection measures significantly differed across the type of mining activity ($p < 0.001$). Barriers of workers to the implementation of relevant adaptation strategies (inadequate knowledge of coping and adaptive behaviour, lack of regular training on adaptation measures, lack of specific heat-related policy regulations, lack of management commitment, and the lack of access to innovative technology and equipment) also differed across the type of mining activity ($p < 0.001$). Adaptation policy options and recommendations centred on overcoming the barriers that constrain the adaptive capacity of workers and employers has the potential to reduce workers' vulnerability to occupational heat stress.

Keywords: Adaptation strategies; barriers; Ghana; mining workers; occupational heat stress; social protection

1. Introduction

Excessive heat exposure based on intensifying global temperatures and climate warming is seen as a potential existential risk to humans, the environment and global development (United Nations, 2009). In particular, extreme heat exposure in workplaces is a recognised fundamental danger to the physiological health, safety, economic productivity, psychological and social lives of working people (Kjellstrom et al., 2016a; Kjellstrom et al., 2016b; Nunfam et al., 2019a). Several studies have shown that indoor and outdoor workers are at risk of heat exposure when they work in hot and humid conditions driven by (1) environmental-related factors (e.g. high temperature and humidity, wind speed, and radiant heat), (2) occupational-based factors (e.g. physical workload, clothing/equipment, shade, and cooling systems) and (3) personal susceptibility factors (e.g. age, alcohol and drug use, medical condition, acclimatisation level, rehydration, and metabolism rate) (Hosokawa et al., 2019; Parsons, 2014; Sugg et al., 2018; Uejio et al., 2018). Conditions of excessive heat exposure impede the workers' body to respond to thermoregulation, and core body temperature eventually increases, resulting in heat-related morbidities and mortality (Kjellstrom et al., 2018; Lundgren et al., 2013). For this reason, the primary development agenda of the world dubbed the United Nation's Sustainable Development Goals has been designed

to improve the lives of people. The Sustainable Development Goals accentuate the need to promote healthy lives and well-being, guarantee decent jobs and economic growth, and fight increasing temperature and other climate change impacts (Leal Filho et al., 2018; United Nations, 2015; Xue et al., 2018).

In tropical and sub-tropical areas of the world, the occurrences of rising heat exposure in work and living environments are being complicated by episodes of high temperature and relative humidity (Kjellstrom et al., 2016a; Kjellstrom et al., 2016b). Evidence in several studies have shown the occurrence and impact of heatwaves and global warming in tropical regions (e.g., parts of Australia, Asia, United States, Africa) of the world (Dosio, 2017; Nageswararao et al., 2019; Natural Capital Economics, 2018; Perkins-Kirkpatrick & Gibson, 2017; Russo et al., 2016; Xiang, et al., 2014b), which have resulted in the need to limit global warming below the threshold of 1.5°C and 2.0°C above pre-industrial level (United Nation Framework Convention on Climate Change, 2010). This condition is being worsened in the context of global climate change due to human-induced Greenhouse Gas emissions (United Nation Framework Convention on Climate Change, 2010). The consequence of heat stress risk and impact on workers due to intense heat exposure are commonly manifested in heat-related comorbidities (e.g., dehydration, heat oedema, heat rash, heat exhaustion, heat cramps, heat syncope and heat stroke) (Kjellstrom et al., 2009b; Krishnamurthy et al., 2017; Lundgren et al., 2013). It is also associated with poor mental judgment, lack of vigilance and concentration, reduced productive capacity and physical performance, and poor social well-being (Kjellstrom et al., 2009b; Lao et al., 2016; Lundgren et al., 2013; Wyon et al., 1996). Empirical and conceptual studies have demonstrated that intensive physical workloads in hot environments coupled with high relative humidity increases core body temperature, reduces physical work capacity, lessens mental concentration, intensifies the possibility of heat-related morbidities and enhances the threat of heat exhaustion and heat-related mortality (Bridger, 2003; Ramsey, 1995; Richards & Hales, 1987).

The quest to combat the risk and magnitude of the impacts of rising global temperature on the world's population, including workers, has stimulated substantial and diverse research interests, international framework conventions, standards, guidelines, conferences, and collaborations within and between United Nation agencies and Intergovernmental organisations. For example, after the First World Climate Conference in Geneva in 1979, the Intergovernmental Panel on Climate Change was established in 1988, the United Nation Framework Convention on Climate Change in 1992, and 24 Conferences of Parties with the first in Berlin in 1995 and the last in 2018 in Poland. Similar notable actions include the Kyoto Protocol and Paris Agreement (Intergovernmental Panel on Climate Change, 2014a; Roberts, 2016; Rogelj et al., 2016; United Nation Framework Convention on Climate Change, 2006). Similarly, guidelines and standards for governments and labour organisations to address the health and safety impacts of heat exposure on workers and employers include International Standards Organisation, National Institute for Occupational Safety and Health, and International Labour Organisation policy guidelines and codes of practice on hot workplace environment (International Labour Organisation, 2001, 2016; International Standards Organisation, 1989; National Institute for Occupational Safety and Health, 2016). Fundamentally, these measures have sought to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to increasing temperature and climate change impacts, and commit to fostering mitigation, adaptation and social protection of people (Intergovernmental Panel on Climate Change, 2014b; Roberts, 2016; Rogelj et al., 2016; United Nation Framework Convention on Climate Change, 2006).

The risk and impact of workplace heat exposure on workers' socioeconomic and health conditions is a significant characteristic of climate change with the tendency to undermine realisation of the Sustainable

Development Goals (Kjellstrom et al., 2016b). Similarly, the extent of risk and impact of heat stress on workers is not only associated with environmental-based heat exposure factors but also linked to their demographic and occupational-related heat exposure vulnerability characteristics (Abrahamsson et al., 2014; ABS, 2016; Bowers et al., 2018; Jia et al., 2016; Xiang et al., 2014a). Hence, preventive and control strategies have been advocated to address occupational heat stress threats to reduce susceptibility, improve resilience and adaptive capacity of working people and their families, socioeconomic units, and communities to ensure sustainable well-being (Intergovernmental Panel on Climate Change, 2014b; Kjellstrom et al., 2016b). Examples of preventive and control strategies include the use of insulation and cooling systems, adequate rehydration, use of work-rest regimes, self-pacing, and continued education and training (Kjellstrom et al., 2016b; Krishnamurthy et al., 2017; National Institute for Occupational Safety and Health, 2016). Aside from mitigation measures, several scholars have identified adaptation and social protection policies and practices as the most appropriate and viable strategies for managing occupational heat stress risk and impacts on people including workers (Spector & Sheffield, 2014; Venugopal et al., 2016; Venugopal et al., 2015; Xiang et al., 2016).

Adaptation encompasses reducing actual workplace heat exposure, avoiding heat stress, and protecting workers from occupational heat stress. Adaptation strategies are exemplified in workers drinking adequate water, resting in the shade, taking work breaks, acclimatising, use of air conditioners and fans, wearing thin/light clothes, and heat stress training programmes (Flocks et al., 2013; Kjellstrom et al., 2016b; Lao et al., 2016; Nunfam et al., 2019b). Successful interventions relating to coping and adaptation strategies mainly comprise engineering solutions, administrative controls, and education and training regimes (Kjellstrom et al., 2016b). It also involves bolstering policy and regulatory guidelines, varying structures of economies to focus on non-outdoor work, compensations for production losses, and social protection of workers (Davies et al., 2009; Giovannetti, 2010; Kjellstrom et al., 2016b; Lundgren et al., 2013). Social protection comprises collective and individualised policies, programmes, and actions directed at preventing, reducing, and eliminating poverty, deprivation, and social exclusion. It also seeks to boost resilience and opportunities by promoting human and social capital of workers to ensure decent and productive employment (UNICEF, 2012; World Bank, 2012). Social safety policies are exemplified in workers' social security, superannuation, and pension schemes as well as insurance policies and labour market interventions (e.g., health insurance, labour standards, minimum wage legislation, credit schemes, and workers interest groups), benevolent reliefs and aids to workplace disaster (Davies et al., 2009).

However, these adaptation and social protection mechanisms are often inadequately implemented at the individual and organisational level to reduce workers' vulnerability and boost their resilience and adaptive capacity to occupational heat stress and climate change (Kjellstrom et al., 2016a; Venugopal et al., 2016). A variety of multifaceted factors, as illustrated in various studies in the US and Australia, for instance, impede the smooth and effective implementation of adaptation to heat exposure, which include inadequate education and awareness campaigns, lack of health and safety training, lack of obligation from management, low compliance of heat stress prevention policies, and insufficient financial resources (Lam et al., 2013; Riley et al., 2012; Xiang et al., 2015).

Several types of outdoor workers (e.g., construction, military, agriculture, manufacturing, and mining) in tropical developing regions, including Ghana, are particularly susceptible to occupational heat stress stemming from rising temperature, outdoor radiant heat, and high humidity, in the context climate change (Kjellstrom et al., 2009b; Lucas et al., 2014). Both the work and living environments of mining workers are often associated

with the risk of heat stress due to actions, events, and interventions typical of surface and underground mining activities. Hence, mining workers in both small-scale mining (SSM) including artisanal mining and large-scale mining (LSM), are at risk of heat stress which is influenced by factors such as high temperature, radiant heat, hot and humid conditions, air movement, heavy physical activity, individual acclimatisation, and use of protective clothing. SSM usually involves local people with inadequate funding and low technical expertise who use labour intensive methods and basic equipment (e.g., shovels, pickaxes, and sluice) to semi-mechanised mining operations (e.g., pumps, blowers, generators, small excavators and washing plants) (McQuilken & Hilson, 2016). This unsafe condition is compounded by the predicted rise in temperature in tropical developing countries like Ghana, which is also associated with major impediments such as poverty, low adaptive capacity, inadequate innovative technology and lack of knowledge of the available heat stress adaptation strategies. This ultimately affects the health and safety, productive ability, and social lives of mining workers leading to loss of productivity and employment opportunities for mining companies (Nunfam et al., 2019b; 2019c).

Given the tendency of workers' vulnerability to occupational heat stress and climate change impacts, effective adaptation and social protection strategies have become crucial to enhance workers' health and safety and improve their productive capacity, physical performance, and social well-being. Hence, several studies with various methods have delved into the concerns about workplace heat stress, climate change and adaptation strategies expressed by various types of workers across the world (Frimpong et al., 2017; Kjellstrom et al., 2016a; Nunfam et al., 2018; Venugopal et al., 2016; Xiang et al., 2016). Thus, Lascar USB temperature and humidity sensors and a calibrated QuestTemp heat stress monitor were used to assess the extent of heat exposure on rural farmers in the northeast of Ghana (Frimpong et al., 2017). Also, a review of the literature was conducted to analyse heat stress, human performance and occupational health for the assessment of global climate change impacts (Kjellstrom et al., 2016) while Nunfam et al. (2018) used a systematic literature review to assess and synthesis evidence on social impacts of occupational heat stress and adaptation strategies of workers. Similarly, interviews and heat stress monitor-QuestTemp 34 were used to measure and provide evidence on social implication of occupational heat stress on public construction migrant workers in Southern India (Venugopal et al., 2016). Furthermore, a cross-sectional questionnaire survey was conducted in South Australia, amongst selected workers and trades to investigate workers' perceptions and behavioural responses towards extreme heat exposure in a warming climate (Xiang et al., 2016). However, current research interest in Ghana's mining industry seems to focus on issues about health and environmental impact assessment of mining activities on air and water pollution, ecosystem and land degradation (Amponsah-Tawiah & Dartey-Baah, 2011; Aryee et al., 2003; Basu et al., 2015; Mensah et al., 2014). Unlike the agricultural and analogous industries (Antwi-Agyei et al., 2013; Frimpong et al., 2016; Frimpong et al., 2015), no studies are highlighting the barriers to adaptation and social protection of mining workers (SSM and LSM) to occupational heat stress in Ghana. Accordingly, case studies from northeast Ghana and a systematic literature review were conducted to assess the barriers that constrain effective implementation of climate change adaptations in sub-Saharan Africa (Antwi-Agyei et al., 2013). Also, household survey and focus group discussion was used to assess the extent of climate change, socioeconomic and cultural barriers of adaptation to heat stress among smallholder farmers in northeast of Ghana (Frimpong et al., 2016). Similarly, a review of Ghana's heat stress, climate change and social protection policies were conducted, and a conceptual model developed as a foundation on which national and international interest in climate change and social protection policies can reduce heat stress impacts on smallholder farmers in Ghana

and sub-Saharan African (Frimpong et al., 2015). This study also assessed the hypothesis that there is no significant difference in the adaptation strategies, social protection measures and the barriers to occupational heat stress adaptation between the two types of mining workers (SSM and LSM).

2. Materials and methods

2.1 Philosophical underpinning and design of the study

The pragmatist philosophical viewpoint guided the methodology employed in this study. Hence, the mixed methods research approach, involving descriptive and explanatory cross-sectional research strategies, was adopted to highlight the research gap (Creswell, 2013; Creswell & Plano Clark, 2017). The mixed methods research design was deemed most appropriate for using both quantitative and qualitative data to provide a complementary and collaborative account of the barriers to occupational heat stress adaptation and social protection strategies of mining workers in Ghana at a point in time (Creswell & Plano Clark, 2017; Mertens, 2015).

2.2 Research location, population, sampling process and sample size

The study was conducted in Ghana's Western Region. The area is noted for both SSM and LSM activities in the country. Ghana is a lower middle-income country located in the West African Sub-region and is characterised by tropical climate conditions with a high predisposition to the risk of heat exposure in the context of low technological advancement, inadequate adaptive capacity and labour intensive mining activities, especially among the SSM companies (Ghana Statistical Service (GSS), 2013; Government of Ghana, 2015). The average temperature of Ghana increased by 1 °C at an average rate (0.21 °C) for each decade from 1960 to 2000 and is predicted to intensify by between 1.0 °C-3.0 °C in 2060 and 1.5 °C-5.2 °C in the 2090s with climate change (Government of Ghana, 2013, 2015). The study focused on mining workers across five mining sites in the Western Region of Ghana as shown in Figure 1 (Nunfam et al., 2019b).

The target population was over a million mining workers including workers directly involved in the SSM sector (McQuilken & Hilson, 2016) and 9,939 workers engaged by 13 LSM companies as of 2015 but have subsequently increased to 10,503 and 11,628 workers in 2016 and 2017 respectively (Ghana Chamber of Mines (GCM), 2018). Five out of the 13 LSM companies and eight out of an estimated 177 SSM companies were purposively selected based on their willingness and interest to participate in the study. Based on the selected mining companies, the study randomly selected 320 respondents consisting of SSM (161) and LSM (159) mining workers who expressed consent and interest to participate in the study.

2.3 Data sources and collection process

Data for this study were elicited from both primary and secondary sources to ensure reliability and adequacy of results. Guided focus group discussions (FGD) and questionnaires constituted the instruments used to obtain primary data from the mining workers, while the secondary data was sourced from theoretical and empirical literature. Also, the FGD consisted of a set of open-ended questions, while the questionnaire comprised both closed-ended and Likert-type question items with statements measured on a response scale including Strongly agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly disagree (SD). The content and design of the instruments were guided by a validated instrument of the High Occupational Temperature Health and Productivity Suppression (HOTHAPS) programme and other empirical studies related to climate change, heat

exposure impact on health, productivity and adaptation strategies (Kjellstrom et al., 2009a; Sheridan, 2007; Xiang et al., 2015). Before data collection, the adapted instruments were reviewed by experts from Edith Cowan University, received ethics approval from the Human Research Ethics Committee of Edith Cowan University (Project # 17487) on 16th August 2017, and pretested in Ghana to ascertain its validity and reliability. The FGD guide and self-reported questionnaire consisted of question items centred on respondents' background characteristics, adaptation strategies, social protection measures, and barriers to the adaptation of mining workers to occupational heat stress. Two FGDs were conducted, one for the SSM (FGD1) and the other for LSM (FGD2) workers who were made up of eight members in each category.

2.4 Data processing and analysis

The qualitative data was processed with NVivo version 11, while the quantitative aspect of the data was processed with IBM Statistical Product and Service Solution (SPSS) version 25 and Microsoft Excel 2016. Thematic analysis was used to synthesise the qualitative data into themes arising from the quotations, texts and extracts of the FGDs. These themes aided in the description and interpretation of data related to any relationships and discrepancies in adaptation strategies of mining workers to occupational heat stress. Similarly, descriptive statistics (e.g., *frequency, percent, M, SD*) and inferential statistics (e.g., *Chi-Square [χ^2]*) were conducted to assess the disparities in the adaptation strategies, social protection measures and the barriers to occupational heat stress adaptation between the SSM and LSM workers at the level of significance ($p < 0.05$). The effect size criteria (very small: 0.01, small: 0.20, medium: 0.50, large: 0.80, very large: 1.20, & huge: 2.0) was employed to determine the extent of significant difference between the variables (Cohen, 1988; Sawilowsky, 2009). Likelihood ratio other than Pearson Chi-Square was used where assumptions of Chi-Square were violated (Fisher, 1935; McHugh, 2013; Yates, 1934). The results of the analysis were illustrated in tables and charts where appropriate.

3. Results

On account of the mixed methods approach the quantitative (self-reported survey) and qualitative (representative quotations of the FGDs) results on barriers to occupational heat stress adaptation of mining workers were illustrated and presented side-by-side. The quantitative results were exemplified with descriptive and inferential statistics and complemented by similar results of the qualitative analysis, which yielded two main themes (adaptation strategies and barriers to adaptation strategies). During the FGDs, participants identified the main heat stress adaptation strategies as being drinking water frequently, wearing light clothes, avoiding alcohol intake and use of snuff, taking work breaks, and using cooling systems. The participants also stated the major barriers to heat stress adaptation as lack of specific heat-related policies, inadequate compliance to existing heat stress warnings, lack of financial resources, and inadequate access to advanced technology for mining work in a hot environment.

3.1 Background characteristics of respondents

In terms of demographic characteristics, the gender composition comprised 80.9% males including SSM (89.4%) and LSM (72.3%), and 19.1% females consisting of SSM (10.6%) and LSM (27.7%). The respondents had a minimum age (21 years) and a maximum age (61 years) with a mean age of 35.1 years ($SD=8.20$). Similarly, 37.8% respondents had secondary education (SSM: 32.3% and LSM: 43.4%), and the least (2.8%) had no formal

education (SSM:5.6% and LSM: 0.0%) (Table 1). Based on work characteristics, the respondents' years of work experience ranged from 1 to 21 years with an average work experience of 7.7 years ($SD=4.43$). Also, 41.8% of respondents consisting of workers of SSM (41.6%) and LSM (42.1%) worked for less than five years while 26.6% respondents comprising workers of SSM (31.1%) and LSM (22.0%) worked for over ten years. Similarly, 62.8% of the respondents including SSM (70.8%) and LSM workers (64.8%) described their workload as heavy while 6.6% of the respondents comprising SSM (5.0%) and LSM (8.2%) workers described their workload as light (Table 1). In addition, 66.0% of the respondents including SSM (58.4%) and LSM (73.6%) workers described their work environment as outdoors while the least (34.0%) of respondents of SSM (41.8%) and LSM (26.4%) described their work environment as indoors. In terms of working around heat sources, the majority (87.2%) respondents comprising both SSM (92.5%) and LSM (81.8%) workers answered in the affirmative. Also, 47.2% of respondents consisting of SSM (68.6%) and LSM (26.5%) workers often worked around heat sources, while only 17.2%, including SSM (8.8%) and LSM (25.7%) workers, did not usually work around heat sources (Table 1).

3.2 Adaptation of mining workers to occupational heat stress

The extent of workers' vulnerability drives their adaptation to the risk and impact of occupational heat stress. The study assessed adaptation of mining workers to occupational heat stress based on their adaptation strategies and social protection measures to occupational heat stress.

3.2.1 Adaptation strategies of mining workers to occupational heat stress

Table 2 shows the results of the variation in adaptation strategies of mining workers to occupational heat stress across the two types of mining workers. The assessment was based on statements related to adaptation strategies of workers measured on a Likert-scale response items. Accordingly, as to whether mining workers frequently drank lots of cool water before feeling thirsty, over 67% of both types of mining workers answered positively. The assertion of drinking lots of water as a way of adapting to occupational heat stress was supported by discussants during the FGDs of the SSM and LSM workers as follows: "So far as you are doing hard work, you will need water, even if you are working at the surface or in the hole [underground] you often drink water" (Participant, SSM workers). "The things we do to protect ourselves include the water we drink" (Participant, LSM workers). Nevertheless, 67.7% of SSM workers as compared to 81.1% of LSM workers answered in the affirmative while 23.6% of SSM workers and 10.6% of LSM workers answered in the negative. The variation in response to the statement that mining workers frequently drank lots of cool water before feeling thirsty between workers of SSM and LSM was statistically significant ($p<.001$) with a small effect size (Table 2).

Responses showed that workers of both SSM (45.3%) and LSM (62.2%) operations agreed to the wearing of loose and light-coloured clothing while working in hot weather conditions. Similarly, participants of the FGD observed that they wore light shirts and overalls that allowed them to feel the air around as shown in the following comments: "If you are working in the heat you wear shirts that are light that will allow air to penetrate it to help you not to feel the heat" (Participant, SSM workers). "As you can see we wear these overall. They are somehow not heavy but loose so you can feel the air blowing when you are in the air condition room or working outside" (Participant, LSM workers). However, 45.3% of SSM compared to LSM (62.2%) workers agreed with wearing loose/light clothing, whilst SSM (16.2%) and LSM (37.8%) workers disagreed. The discrepancy in whether

mining workers wore loose and light-coloured clothing while working in hot weather conditions between SSM and LSM workers was statistically significant ($p < .001$) with large effect size (Table 2).

Furthermore, most workers of both SSM and LSM did not drink coffee, soft drinks, caffeinated energy drinks and alcohol when working in a hot environment. Similarly, the use of drinks like alcohol when working in hot conditions was not supported by members of the FGDs. For instance, a participant of the FGD with the SSM workers indicated that:

“The heat does not go with ‘akpeteshie’ [local alcoholic beverages] for if you are drunk and you enter the hole [underground], it is easy to die, but if you are normal without it, you are able to detect the heat early which usually saves you. If you also smoke and use snuff it is likely the heat stress will affect you” (Participant, SSM workers).

Also, a member of the FGD involving the LSM workers explained that: *“We are not allowed by the company policy to drink alcohol when working. Someone was punished because of [alcoholic] drink”* (Participant, LSM workers). Comparatively, workers of SSM (21.2%) and LSM (47.8%) answered positively while SSM (72.0%) and LSM (46.5%) workers responded negatively. The difference as to whether mining workers drank coffee, soft drinks, caffeinated energy drinks and alcohol when working in hot environment between SSM and LSM workers was statistically significant ($p < .001$) with a small effect size (Table 2).

The responses indicated that the majority of both SSM (80.8%) and LSM (74.8%) workers acknowledged they took regular breaks away from hot conditions in a cooler or shaded area. The following extracts from the FGDs with SSM and LSM workers showed that mining workers took some breaks away from hot weather conditions. *“This work cannot be done without break. We break to eat and rest like 15 to 30 minutes before we start to work again”* (Participant, SSM workers). *“We break for a while like half an hour and cool ourselves in the offices where we do the paperwork and stuff”* (Participant, LSM workers). In comparison, a greater portion (80.8%) of SSM and a lesser proportion of LSM (74.8%) affirmed taking regular breaks away from hot conditions in cooler or shaded area while workers of SSM (19.3%) compared to 22.6% of LSM workers answered otherwise. This distinction in whether mining workers took regular breaks away from hot conditions in a cooler or shaded area across the type of mining workers was statistically significant ($p < .05$) with a small effect size (Table 2).

The majority of the SSM (80.1%) and LSM (86.2%) respondents were of the view that mining workers used mechanical equipment to reduce the need for strenuous physical workload. Relatively, 80.1% of SSM and a slightly higher proportion (86.2%) of LSM workers confirmed that mining workers used mechanical equipment to reduce the need for strenuous physical workload while 17.4% of SSM and 11.9% of LSM workers disagreed (Table 2). However, the difference in mining workers’ use of mechanical equipment to reduce the need for strenuous physical workload between SSM and LSM workers was not statistically significant.

Similarly, respondents of SSM (38.5%) compared to respondents of LSM (85.0%) agreed that mining workers planned and carried out heavy routine outdoor work during the early morning or evening hours or in shaded areas during hot weather. In contrast, 16.8% of SSM workers and 9.4% of LSM workers answered in the negative. The variation in whether mining workers planned and carried out heavy routine outdoor work during the early morning or evening hours or in shaded areas during hot weather was statistically significant ($p < .001$) with a medium effect size (Table 2).

Most of the SSM and LSM workers participated in training programmes on working safely in the heat. Fewer (77.0%) SSM workers than LSM workers (91.2%) acknowledged that they participated in training programmes on working safely in the heat, whereas 21.1% of SSM workers and 6.9% of LSM workers disagreed.

The discrepancy in mining workers participation in training programmes on working safely in the heat was statistically significant ($p<.001$) with a small effect size (Table 2).

With regards to whether mining workers shared unavoidable heavier jobs and rotated jobs on shifts schedules, over 85% of both SSM and LSM workers responded positively. Thus, 85.7% and 88.7% of SSM and LSM workers respectively answered in the affirmative but SSM (11.2%) and LSM (9.4%) workers responded otherwise. The variation in mining workers response to sharing unavoidable heavier jobs and rotated jobs on shifts schedules was statistically significant ($p<.001$) with a small effect size (Table 2).

Additionally, a lower proportion (32.3%) of SSM workers and a higher portion (50.9%) of LSM workers claimed that mining workers slowed down work at their own pace to meet hot weather conditions, while much more workers of SSM (48.8%) than LSM (10.7%) were undecided. However, more SSM workers (19.3%) than LSM workers (7.5%) were in disagreement. The distinction in mining workers' views of slowing down work at their own pace to meet hot weather conditions was statistically significant ($p<.001$) again with a small effect size (Table 2).

The majority (> 70%) of SSM and LSM workers were in agreement that mining workers used personal protective equipment like sunglasses, wide-brimmed hats and hand gloves during hot weather conditions. Comparatively, 72.5% of SSM workers less than 90.0% of LSM workers responded affirmatively, while 19.3% of SSM workers and 7.5% of LSM workers answered negatively. The difference in mining workers use of personal protective equipment like sunglasses, wide-brimmed hats, and hand gloves during hot weather conditions were statistically significant ($p<.05$) with a small effect size (Table 2).

The responses demonstrated that over 76% of respondents (SSM and LSM) confirmed that mining workers use cooling systems like air conditions and electric fans during hot weather conditions. Participants re-echoed the use of cooling mechanisms in hot weather conditions during the FGDs. This is evident in the following statements: *"If you are working under air condition or using a fan for hours, you will not sweat and will not feel the heat"* (Participant, SSM workers). *"The things we do to protect ourselves include..., the air conditions we use and we go to cool places for fresh air for a while"* (Participant, LSM workers). Respondents' divergent opinions showed that a little more (77.0%) SSM and less (76.1%) LSM workers affirmed the use of cooling systems during hot conditions while very similar proportion of SSM (20.5%) and LSM (20.7%) workers had a contrary view. The contrast in mining workers use of cooling systems like air conditions and electric fans during hot weather conditions was statistically significant ($p<.001$) with a small effect size (Table 2).

Lastly, as shown in Table 2, more than 76% (SSM and LSM) workers acknowledged that mining workers live in houses designed to allow proper air flow and escape of heat through windows and roofs. Considerably, more (80.1%) SSM workers compared to LSM (76.7%) workers answered in the affirmative whereas 19.2% of SSM and 22.6% of LSM workers disagreed. The variation in respondents' view that mining workers live in houses designed to allow proper air flow and escape of heat through windows and roofs were statistically significant ($p<.001$) with a small effect size.

3.2.2 Social protection measures of mining workers to occupational heat stress

Fig. 2 shows the results of the variation in social protection strategies of mining workers to cope with occupational heat stress, highlighting the differences between SSM and LSM workers. Social protection measures commonly adopted among the respondents include national health insurance (35.4%), compensation scheme

(18.1%), member of a labour union (14.6%), and work-based health insurance (13.4%). Similarly, the discrepancies in the proportion of respondents who identified national health insurance (SSM: 50.3% vs LSM:26.1%), compensation scheme (SSM: 5.1% vs LSM:26.4%), member of labour union (SSM: 8.1% vs LSM:18.6%), and work-based health insurance (SSM: 10.5% vs LSM:15.4%) were statistically significant ($p<.001$) with a small effect size.

3.3 Barriers to the effective adaptation of mining workers to occupational heat stress

Even though there are adaptation and social protection measures to occupational heat stress among mining workers, there are factors that impede the effective implementation of the workers' adaptation strategies. Consequently, a high proportion (over 85%) of both SSM and LSM workers alluded to inadequate knowledge of coping and adaptive behaviour as a challenge to effective execution of the adaptation and social protection measures to occupational heat stress. Fewer SSM workers (85.7%) than LSM workers (91.2%) confirmed the challenge of inadequate knowledge of coping and adaptive behaviour, whilst more SSM (10.0%) than the LSM workers (8.8%) disagreed with this impediment. The difference in inadequate knowledge of coping and adaptive behaviour between SSM and LSM workers was statistically significant ($p<.001$) with a small effect size (Table 3).

The majority (> 83%) of SSM and LSM workers agreed to lack of regular training on occupational heat stress risk, work safety and adaptation measures as an impediment to effective implementation of adaptation and social protection strategies to heat stress. Thus, virtually similar proportions of SSM (83.8%) and LSM (84.9%) workers answered in the affirmative whilst fewer (12.5%) SSM and more (15.1%) LSM workers answered in the negative. The variation in lack of regular training on heat stress risk, work safety and adaptation measures between SSM and LSM workers was statistically significant ($p<.001$) with a small effect size (Table 3).

Furthermore, more than 89% of both SSM and LSM workers acknowledged that lack of specific heat-related policies and regulation on work health and safety was a barrier to effective implementation of occupational heat stress adaptation and social protection of mining workers. The following excerpts from the FGDs with SSM and LSM affirm the lack of specific heat-related policies on work health and safety as a barriers to effectively implementing occupational heat stress adaptation.

"There is no specific regulation that guides our work in the heat as it is the case with the big mining companies. But we wear loose and light clothes and use blowers when working underground to cool it. However, they are not enough like how you're required to follow specific work rules and policies in the big mining companies, so you don't get injured or ill from the exposure to dust, heat, or chemicals" (Participant, SSM worker).

"There are regulations and policies on workers' health and safety in the mines, but there is a need for more specific policies related to heat stress as it is the case for guidelines on exposure to dust, noise vibration, and chemical hazards in the mines" (Participant, LSM worker).

Irrespective of their area of employment, nearly the same SSM (85.1%) LSM(84.9%) workers agreed to lack of specific heat-related policies and regulation on work health and safety as a barrier. However, less (8.7%) SSM and more (9.4%) LSM workers disagreed. The difference in lack of specific heat-related policies and regulation on work health and safety as a barrier to occupational heat stress adaptation was statistically significant ($p<.001$) with a small effect size (Table 3).

In addition, the majority (>84%) of respondents identified with poor compliance and implementation of heat stress guidelines, policies and programmes as a factor that inhibits effective adaptation to occupational heat

stress. The accounts of the participants (SSM and LSM) during the FGDs as exemplified in the following statements indicate poor compliance to existing heat advise or warning as a barrier to heat stress adaptation.

"We are advised to drink more water, wear light clothes, take some break or avoid alcoholic drinks when working in hot conditions to prevent headaches, injury or collapse from the effect of the heat. Some workers don't always follow these guidelines; instead, they don't drink more water unless they are thirsty and others drink alcohol after work" (Participant, SSM worker).

"There are rules and regulations for the health and safety of workers from heat exposure; how to manage heat and stuff, but sometimes because of work pressure from the top and the need to meet targets and stuff some workers try to turn a blind eye or overlook the policies at work without taking some time to do risk assessment" (Participant, LSM worker).

Almost the same proportion of SSM (85.1%) workers and LSM (84.9%) workers supported the statement that poor compliance and implementation of heat stress guidelines policies and programmes inhibited effective adaptation to occupational heat stress, whereas less (9.9%) SSM and more (14.5%) were not in support. The discrepancy in poor compliance and implementation of heat stress guidelines, policies and programmes as a barrier to occupational heat stress adaptation was statistically significant ($p < .05$) with a small effect size (Table 3).

Also, over 69% (both SSM and LSM) workers answered positively to the statement that inadequate financial resources to support engineering control of heat stress impaired effective implementation of occupational heat stress adaptation. The opinions shared by the discussants (SSM and LSM) during FGDs give credence to the assertion that inadequate financial resource to support engineering control of heat stress hampered how occupational heat stress adaptation was implemented. For instance, a participant of the SSM workers pointed to this view as follows:

"If you look at the large mining companies ... they have a lot of financial investments from foreign companies so they can afford to buy air conditions and other things which help to cool the heat. But for us in the small mining, we don't have much money to buy all these machines and equipment. So we use blowers to help reduce the heat in the holes" (Participant, SSM worker).

Similarly, a discussant with LSM workers in the FGDs indicated the inadequate financial resources to support engineering control as a barrier in the following statement: *"I see one of the barriers to be not using enough resources to find new technology for modern mining approach in the heat"*. Mostly, a greater proportion (82.0%) of SSM and a fewer portion (69.8%) answered in agreement to inadequate financial resources to support engineering control of heat stress as a factor that hinders adaptation to occupational heat stress while less (5.8%) and far more (25.8%) answered in disagreement. The variation in inadequate financial resources to support engineering control of heat stress as an impediment to the effective operation of occupational heat stress adaptation was statistically significant ($p < .05$) with a small effect size (Table 3).

Moreover, more than 76% of respondents supported the statement that lack of management commitment to heat-related health and safety measures thwart effective implementation of occupational heat stress adaptation. Fewer (76.4%) SSM and more (83.0%) LSM workers answered in the affirmation that lack of management commitment to heat-related health and safety measures impeded effective adaptation and social protection strategies to occupational heat stress. In contrast, more (18.0%) and less (15.7%) answered in the negative. The difference in the lack of management commitment to heat-related health and safety measures between SSM and LSM workers that impede effective implementation of occupational heat stress adaptation was statistically significant ($p < .001$) with a small effect size (Table 3).

Finally, as to whether the lack of access to innovative technology and equipment for mining work in hot weather conditions weakened the effective execution of occupational heat stress adaptation, the majority (>80%) of the respondents answered positively. Comparable evidence from the FGDs re-echoed lack of access to advanced technology and equipment for mining work in hot conditions as a barrier to heat stress adaptation. This is evident in the following extracts:

“This is just a small mining company. We don’t have access to all these modern technology and machines as it is the case with the large mining companies where I used to work. Over here we rent and use small equipment like excavators, ‘chamfan’, and other machines to do the mining” (Participant, SSM worker).

“...some organisation may not have access to every modern technology, but it is important for this mining company to improve access to robust modern technology and equipment for mining in hot areas, especially for the underground mining, even though that advanced technology can be costly” (Participant, LSM worker).

Comparatively, less (82.0%) SSM and more (84.9%) LSM workers affirmed that lack of access to innovative technology and equipment for mining work in hot weather conditions inhibited adequate occupational heat stress adaptation while nearly the same proportion of SSM (13.6%) and LSM(13.8%) workers was in disagreement. The dissimilarity in lack of access to innovative technology and equipment for mining work in hot weather conditions as a factor that affects effective implementation of occupational heat stress adaptation was statistically significant ($p<.001$) with a small effect size (Table 3).

4. Discussion

To the best of our knowledge this is the first and most contemporary thorough study using the mixed methods strategy to assess the barriers to occupational heat stress adaptation and social protection strategies of mining workers in Ghana. Similarly, several studies have employed mixed methods research design as an important strategy to assess issues related to barriers to climate change and heat stress adaptation and behaviour change (Birchall et al., 2016; Hass & Ellis, 2019; Semenza et al., 2008; Sheridan, 2007; Tanyanyiwa et al., 2015). Hence, the narrative in this study was based on results of self-reported survey and FGDs amongst SSM and LSM workers and related to theoretical and empirical studies to give an account of mining workers’ background characteristics, adaptation strategies to occupational heat stress, social protection measures, and barriers to occupational heat stress adaptation strategies to enlighten policy decisions in the mining industry.

4.1. Mining workers’ background characteristics

The background information consisted of the demographic and work characteristics of mining workers. More males compared to their female colleagues dominated the gender composition of both SSM and LSM workers in the study. Unequal gender representation with male dominance is not atypical in the mining industry (Abrahamsson et al., 2014; ABS, 2016; Bowers et al., 2018). The younger and energetic workers (SSM and LSM) compared to the older counterparts were more likely to work for extra hours for more income irrespective of the risk of heat-related morbidity and its attendant impacts on productive capacity and social well-being (Jia et al., 2016; Xiang et al., 2014a). Most SSM workers had only basic or no formal education, while most LSM workers had at least basic education to tertiary education. The extent of mining workers’ attitude and behaviour based on their sex composition, age and education should be considered in workplace health and safety policies aimed to enhance adaptive capacity and resilience to occupational heat stress.

Most SSM and LSM workers had an average of seven years work experience, with a heavy workload in outdoor work environments and around heat sources and they generally lacked adequate adaptive capacity and resilience, thus placing them at risk of suffering occupational heat-related morbidity and mortality. Workplace health and safety management policies based on heat exposure risk and impact, adaptation and social protection measures to occupational heat stress tend to facilitate workers' adaptive capacity, boost resilience and improve productivity. Occupation health and safety policies founded on reduced workload, working hours on humid and hot days, physically demanding occupations, outdoor work often done near heat sources, and sustained awareness, education and training on heat exposure risk and adaptation can improve workers' adaptive capacity and resilience (Nunfam et al., 2019b).

4.2. Adaptation strategies to occupational heat stress

Various studies in the last decade have underscored the socioeconomic, health, safety, and productivity consequences and adaptation experiences of heat exposed workers in hot and humid workplaces and living environments (Kjellstrom et al., 2018; Kjellstrom et al., 2016b; Krishnamurthy et al., 2017; Nunfam et al., 2018). The socioeconomic, health and safety ramifications of occupational heat stress of such workers include heat exposure-related illnesses, injuries, poor social well-being, loss of productive capacity, lack of concentration and poor mental judgement (Lao et al., 2016; Nunfam et al., 2019c; Venugopal et al., 2016). Hence, adaptation strategies have emerged as one of the important and locally based appropriate options for avoiding and adjusting to occupational heat stress risk and impacts. Generally, though most workers across both types of mining employed adequate occupational heat adaptation strategies, there were some disparities between SSM and LSM workers. For instance, more SSM workers than LSM workers took regular breaks away from hot conditions in a cooler or shaded area, used cooling systems like air conditioners and electric fans during hot weather conditions, and lived in houses designed to allow proper air flow and escape of heat through windows and roofs. Although electric fans are cheaper options to other cooling systems (e.g., air conditioners) of the body, they can only be more effective at cooling the body in hot and humid condition rather than hot and dry conditions. Studies have shown that fan use above heat index of 37.2°C (99°F) increases the heat stress the body needs to deal with (United States Environmental Protection Agency, 2006). Similarly, fan use has the benefit to lower core temperature and cardiovascular strain, and improve thermal comfort in hot and humid condition with heat index (56 °C [133°F]). However, it can be harmful when used in very hot, dry conditions regardless of a lower heat index (46 °C [115°F]) (Morris et al., 2019). However, more workers of LSM compared to SSM regularly drank a lot of cool water before feeling thirsty, wore loose and light-coloured clothing while working in hot weather conditions, used mechanical equipment to reduce the need for strenuous physical workload, participated in training programmes on working safely in the heat, shared unavoidable heavier jobs and rotated jobs on shift schedules, and used personal protective equipment like sunglasses, wide-brimmed hats, and hand gloves during hot weather conditions. The specified adaptation strategies and the significant discrepancies in the adaptation strategies of mining workers to occupational heat stress across the type of mining activity are valuable factors with considerable implications for workplace health and safety policies geared towards protecting workers from occupational heat stress hazards and impacts. Multiple studies have re-echoed similar findings of this study and emphasised the relevance of effective implementation of adaptation strategies (e.g., water ingestion, rehydration, taking regular rests and breaks, use of cooling systems and housing designs) in safeguarding workers from heat-related morbidity, reduced productive

ability, social well-being and possible mortality (Flocks et al., 2013; Nunfam et al., 2019c; Pradhan et al., 2013; Xiang et al., 2016). Also, the findings are consistent with numerous studies which state that mitigation and adaptation to heat exposure and climate change relate to engineering and administrative controls, training and education, compensation schemes, and social protection measure of heat exposed workers (Kjellstrom et al., 2016b; National Institute for Occupational Safety and Health, 2016). Thus, a sustained awareness crusade and effective implementation of heat exposure policies facilitate workers' adaptive capacity and resilience. It also boosts policy decisions and efforts at combating intensifying temperature and other impacts of global climate warming.

4.3. Social protection measures to occupational heat stress

Increasing temperature is steadily worsening the socioeconomic, safety and health repercussions of occupational heat stress on workers. Previous studies show that apart from mitigation and adaptation strategies, adequate resources directed at planning and enforcing social protection policies tends to reduce susceptibility and hazards to heat stress and enhance adaptive capacity and resilience of workers (Kjellstrom et al., 2016b; Venugopal et al., 2016; Venugopal et al., 2015). Accordingly, the results of the study based on social protection measures (e.g., national health insurance, compensation, work-based health insurance, member of labour and credit unions), as corroborated in various conceptual and empirical studies, highlight the importance of workers' knowledge and use of social protection strategies in shielding employers and employees from the dangers of excessive heat exposure (Davies et al., 2009; Frimpong et al., 2015; Kjellstrom et al., 2016b). Social protection strategies of workers across both types of mining was quite adequate, however, SSM workers adopted more of national health insurance while LSM used more of compensation, work-based health insurance and membership of labour. The need for social protection policies as one of the variables of safeguarding workers is informed by international standards, guidelines and framework conventions targeted at reducing vulnerability and impacts of occupational heat exposure driven by increasing thermal stress (International Labour Organisation, 2016; International Standards Organisation, 1989; National Institute for Occupational Safety and Health, 2016). Hence, heat exposure management and workplace policies and actions intended to ensure workers' health, safety, efficiency, productive capacity and social well-being need to integrate social protection measures aimed at reducing vulnerability and promoting adaptive capacity and resilience.

4.4. Barriers to effective execution of occupational heat stress adaptation

Essentially, comparable results on barriers to adaptation strategies of mining workers to occupational heat stress have been reported in analogous studies (Frimpong et al., 2016; Lam et al., 2013; Xiang et al., 2015). The factors that impede effective implementation of occupational heat stress adaptation strategies of workers varied significantly between workers of SSM and LSM. For example, lack of adequate knowledge and coping behaviour, lack of regular training on heat stress, work safety and adaptation measures, lack of management's commitment to heat-related health and safety measures and lack of access to innovative technology and equipment for mining work in hot weather condition were more strongly associated with LSM compared to SSM. However, issues that hinder more SSM than LSM workers from effectively executing the adaptation strategies to occupational heat stress included lack of specific heat-related policies and regulation on work health and safety, poor compliance

and implementation of heat stress guideline, policies and programmes, and inadequate financial resources to support engineering control of heat stress. Similarly, socio-cultural and economic barriers, lack of information and knowledge, policy and regulatory impediments were found to constrain the capacity of workers from various sectors (e.g., agriculture, manufacturing, mining, and construction) to effectively manage risks and impacts associated with heat exposure (Frimpong et al., 2016; Natural Capital Economics, 2018; Xiang et al., 2014a). The evidence of substantial differences in barriers experienced by mining workers to effectively carry out the adaptation strategies to occupational heat stress across the type of mining activity was most likely linked to the significant variations in workers' educational level, their work characteristics, and previous occupational heat stress risk experience (Nunfam et al., 2019b).

5. Conclusions and policy recommendations

SSM and LSM workers affirmed the use of adaptation and social protection measures to reduce or adjust to occupational heat stress and the barriers that impede effective implementation of the adaptation strategies of mining workers. The workers' adaptation strategies, social protection measures, and the barriers to occupational heat stress adaptation differed significantly between SSM and LSM workers. SSM workers resorted to using regular breaks, cooling systems, and housing designs while LSM workers were associated more with frequently drinking water, wearing loose and light-coloured clothing, participating in training programmes, sharing and rotating unavoidable heavier jobs, and greater use of PPE as occupational heat stress adaptation strategies. Similarly, SSM workers relied on the national health insurance whereas the LSM workers tended to use strategies such as compensation, labour union and work-based health insurance more as social protection measures. Furthermore, SSM workers were inhibited by lack of specific heat-related policies and regulations and poor compliance and implementation of heat stress guidelines while LSM workers were challenged by inadequate knowledge of coping and adaptive behaviour, lack of regular training on heat stress risk, safety and adaptation measures, and lack of management commitment to heat-related health and safety measures, and the lack of access to innovative technology and equipment for mining work in hot weather conditions.

The observed variations in occupational heat stress adaptation and social protection strategies, as well as the barriers to occupational heat stress adaptation strategies should inform policy framework on occupational health and safety and workplace heat stress management in Ghana's mining industry. Future research on access to innovative technology for mining activities in the context of heat exposure adaptation will be valuable in the mining industry. Stakeholders in the the country's mining sector, including workers, should be at the centre of occupational heat stress adaptation policy planning, formulation and implementation to ensure the adequate management of workplace heat exposure dangers associated with global climate warming. Adaptation policy should focus on reducing impediments and barriers constraining workers and employers' capacity to manage heat exposure risk and impacts. Thus, a combined effort involving important stakeholders in the mining industry can significantly promote workers' health, safety, productive ability and social well-being as well as improve their adaptive capacity and enlighten policy formation and operation in the mining industry.

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Figures 1 and 2

Fig 1. A map showing five mining sites located in the Western Region of Ghana

Source: Department of Geography and Regional Planning, University of Cape Coast, 2018

(Pearson Chi-Square: $\chi^2(6) = 64.433$, $p < .001$, $V = .449$)

Fig. 2. Results of the difference in social protection measures of mining workers to occupational heat stress across the type of mining activity

Source: Field survey, 2017

Tables 1 to 3

Table 1. Background characteristics of the mining workers (n=320); SSM=Small-scale mining; LSM=Large-scale mining; f=frequency; M=mean; SD=Standard deviation

Characteristics	Type of mining activity		Total F(%)
	SSM F(%)	LSM F(%)	
<i>Sex</i>			
Male	144(89.4)	115(72.3)	259(80.9)
Female	17(10.6)	44(27.7)	61(19.1)
<i>Age group (M = 35.1; SD = 8.20)</i>			
< 25	16(9.9)	11(6.9)	27(8.4)
25-34	72(44.7)	68(42.8)	140(43.8)
35-44	52(32.3)	57(35.9)	109(34.1)
45-54	18(11.2)	17(10.7)	35(10.9)
55+	3(1.9)	6(3.7)	9(2.8)
<i>Level of education</i>			
No formal education	9(5.6)	0(0.0)	9(2.8)
Basic education	79(49.1)	22(13.8)	101(31.6)
Secondary education	52(32.3)	69(43.4)	121(37.8)
Tertiary education	21(13.0)	68(42.8)	89(27.8)
<i>Years of working experience (M = 7.71; SD = 4.434)</i>			
<5	67(41.6)	67(42.1)	134(41.8)
5-9	44(27.3)	57(35.9)	101(31.6)
10+	50(31.1)	35(22.0)	85(26.6)
<i>Workload</i>			
Light	8(5.0)	13(8.2)	21(6.6)
Medium	39(24.2)	59(37.1)	98(30.6)
Heavy	114(70.8)	87(54.8)	201(62.8)
<i>Working hours</i>			
8-10	124(77.0)	32(20.1)	156(48.8)
11-13	34(21.1)	127(79.9)	161(50.3)
14-16	3(1.9)	0(0.0)	3(0.9)
<i>Workplace environment</i>			
Outdoor	94(54.8)	117(73.6)	211(66.0)
Indoor	67(41.8)	42(26.4)	109(34.0)
<i>Work around heat sources</i>			
Yes	149(92.5)	130(81.8)	279(87.2)
No	12(7.5)	29(18.2)	41(12.8)
<i>Frequency of work around heat sources</i>			
Never	14(8.8)	41(25.7)	55(17.2)
Sometimes	26(16.1)	49(30.8)	75(23.4)
Often	109(68.8)	42(26.5)	151(47.2)
No response	12(7.5)	27(17.0)	39(12.2)

Source: Field survey, 2017

Table 2: Results of the difference in adaptation strategies of mining workers to occupational heat stress across the type of mining activity (Chi-Square test) ($n=320$; $n(SSM)=161$; $n(LSM)=159$)

Statement	SA		A		U		D		SD		Chi-Square
	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	
Frequently drink lots of cool water before feeling thirsty	19.9	43.4	47.8	37.7	8.7	8.2	8.7	7.5	14.9	3.1	$\chi^2(4) = 28.292, p < .001$, Cramer's $V = .297$
Wear loose and light-coloured clothing while working in hot weather conditions	13.0	30.8	32.3	31.4	38.5	0.0	7.5	29.6	8.7	8.2	$\chi^2(4) = 94.030, p < .001$, Cramer's $V = .542$
Drink coffee, soft drinks, caffeinated energy drinks and alcohol when working in hot environment and tired	7.5	17.6	13.7	30.2	6.8	5.7	16.1	15.7	55.9	30.8	$\chi^2(4) = 28.359, p < .001$, Cramer's $V = .298$
Take regular breaks away from hot conditions in a cooler or shaded area	60.9	39.0	19.9	35.8	0.0	2.5	5.6	11.9	13.7	10.7	$\chi^2(4) = 23.323, p < .05$, Cramer's $V = .270$
Used to working in the heat without any medication to cope with heat stress	13.0	25.2	56.5	15.7	8.7	5.7	10.6	28.3	11.2	25.2	$\chi^2(4) = 65.537, p < .05$, Cramer's $V = .453$
Use mechanical equipment to reduce the need for strenuous physical workload	21.7	34.6	58.4	51.6	2.5	1.9	8.7	6.9	8.7	5.0	$\chi^2(4) = 7.390, p > .05$
Plan and carry out heavy routine outdoor work during the early morning or evening hours or in shaded areas during hot weather	14.3	40.3	24.2	44.7	44.7	5.7	8.1	6.3	8.7	3.1	$\chi^2(4) = 82.276, p < .001$, Cramer's $V = .507$
Participate in training programmes on working safely in the heat	26.7	52.2	50.3	39.0	1.9	1.9	9.3	4.4	11.8	2.5	$\chi^2(4) = 27.903, p < .001$, Cramer's $V = .295$
Share unavoidable heavier jobs and rotate jobs on shift schedules	68.3	42.8	17.4	45.9	3.1	1.9	3.1	3.1	8.1	6.3	$\chi^2(4) = 31.661, p < .001$, Cramer's $V = .310$
Slow down work at my pace to meet hot weather conditions	19.9	31.4	12.4	19.5	48.4	10.7	9.3	17.0	9.9	21.4	$\chi^2(4) = 55.390, p < .001$, Cramer's $V = .416$
Use personal protective equipment like sunglasses, wide-brimmed hats and hand gloves during hot weather conditions	64.0	64.2	11.2	25.8	5.6	2.5	7.5	2.5	11.8	5.0	$\chi^2(4) = 19.364, p < .05$, Cramer's $V = .246$
Use cooling systems like air conditions and electric fans during hot weather conditions	59.0	36.5	18.0	39.6	2.5	3.1	8.1	17.6	12.4	3.1	$\chi^2(4) = 36.101, p < .001$, Cramer's $V = .336$
Live in a house designed to allow proper air flow and escape of heat through windows and roofs	64.6	48.4	15.5	28.3	0.6	0.6	6.2	18.2	13.0	4.4	$\chi^2(4) = 25.987, p < .001$, Cramer's $V = .285$

Source: Field survey, 2017

Table 3: Results of the difference in barriers to effective adaptation strategies of mining workers to occupational heat stress across the type of mining activity (Chi-Square test) ($n=320$; $n(SSM)=161$; $n(LSM)=159$)

Statement	SA		A		U		D		SD		Chi-Square
	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	SSM %	LSM %	
Inadequate knowledge of coping and adaptive behaviour	60.2	23.3	25.5	67.9	4.3	0.0	5.0	4.4	5.0	4.4	$\chi^2(4) = 64.117, p < .001$, Cramer's $V = .448$
Lack of regular training on heat stress risk, work safety and adaptation measures	59.0	34.6	24.8	50.3	3.7	0.0	7.5	9.4	5.0	5.7	$\chi^2(4) = 30.381, p < .001$, Cramer's $V = .308$
Lack of specific heat-related policies and regulation on work health and safety	57.1	34.0	32.3	56.0	1.9	0.6	6.2	5.0	2.5	4.4	$\chi^2(4) = 21.628, p < .001$, Cramer's $V = .260$
Poor compliance and implementation of heat stress guidelines, policies and programme	54.7	45.3	30.4	39.6	5.0	0.6	6.8	5.7	3.1	8.8	$\chi^2(4) = 23.240, p < .05$, Cramer's $V = .203$
Inadequate financial resources to support engineering control of heat stress	53.4	31.4	28.6	38.4	5.0	4.4	5.0	13.2	1.8	12.6	$\chi^2(4) = 19.000, p < .05$, Cramer's $V = .244$
Lack of management commitment to heat-related health and safety measures	57.8	24.5	18.6	58.5	5.6	1.3	9.9	12.6	8.1	3.1	$\chi^2(4) = 62.804, p < .001$, Cramer's $V = .433$
Lack of access to innovative technology and equipment for mining work in hot weather conditions	62.7	27.0	19.3	57.9	4.3	1.3	9.9	10.7	3.7	3.1	$\chi^2(4) = 56.502, p < .001$, Cramer's $V = .420$

Source: Field survey, 2017