

# Dehydration is a Health and Safety Concern for Surface Mine Workers.

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## INTRODUCTION

The mining industry is a significant contributor to the gross domestic product in Australia, with over 150 mine sites in Queensland alone. Queensland is also commonly referred to as the sunshine state and is known for its hot and humid summer days. Air temperature commonly exceeds 35 °C in the summer months with humidity above 50 %. Such climatic conditions impose significant heat stress on mine workers in addition to the metabolic cost of manual labour and the requirement to wear protective clothing. Health and safety concerns of work in the heat include reduced work capacity, increased risk of accident and injury, dehydration, and the development of heat illness. A substantial amount of research has focused on heat stress in underground mines, however, little attention has been given to surface mining operations.

An underground mine in Australia recorded 106 cases of heat exhaustion in a 12 month period<sup>6</sup>. To the author's knowledge, only one study has reported heat illness among surface mine workers, and found a higher incidence among this population compared to underground workers<sup>4</sup>. However it was speculated that commonly not all cases of heat exhaustion were reported to the Mine Safety and Health Administration. With the possibility of a higher incidence of heat illness among surface miners, the purpose of part A of this study was to investigate if surface mine workers had experienced symptoms of heat illness. Whilst experiencing symptoms of heat illness may not indicate actual cases of heat illness, it does suggest a high degree of heat strain and that the physiological systems of the body may be struggling to meet the demands of thermoregulation. The purpose of part B of this study was to monitor heat strain (core body temperature, heart rate, and hydration status) among a sample of surface mine workers.

## METHODS

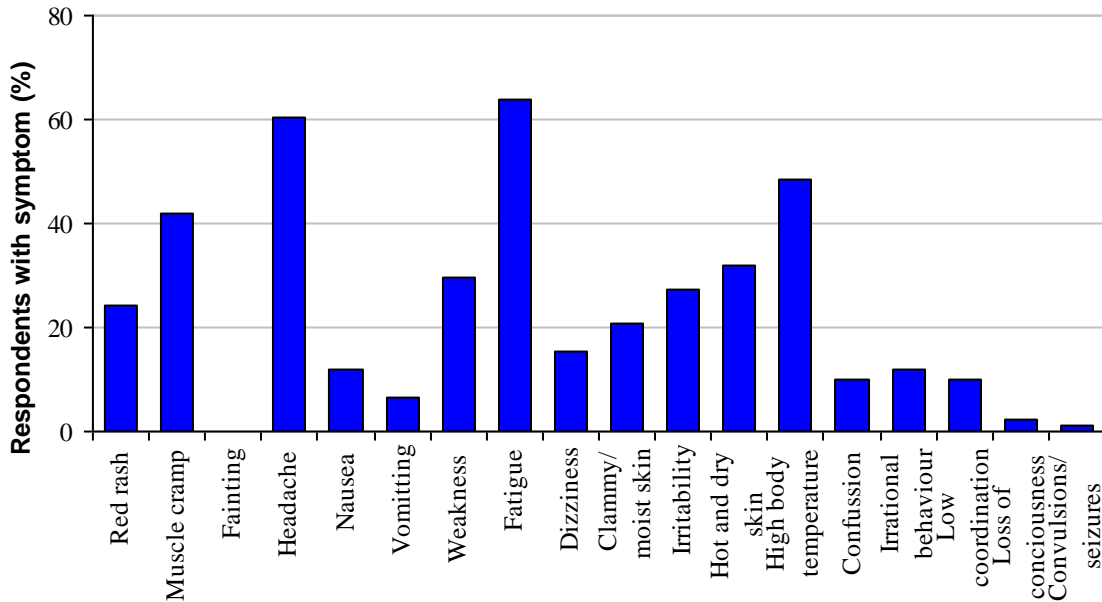
### Part A:

Ninety-one surface mine workers across three mine sites completed a heat stress questionnaire. Participants were asked to indicate if they had experienced symptoms of heat illness during work in the past 12 months and, if experienced, how often each symptom occurred (once or more than once). Self-report age, height, weight, and time spent in recreational physical activity per week (> 150 minutes (sufficient), < 150 minutes (insufficient), no exercise (sedentary)) information were also collected. A urine colour chart<sup>1</sup> was provided and participants indicated their average urine colour during work, which was used to estimate hydration status (colours 1 and 2 - well hydrated, colours 3 and 4 - minimal dehydration, colours  $\geq 5$  - significant dehydration)<sup>2</sup>. Independent samples t-test and Pearson chi-square were used in statistical analysis.

## Part B:

A job category identified as high risk was sampled in Part B. Fifteen blast crew personnel (14 male and 1 female) at a surface mine site in Queensland gave their written consent to participate in this ethically approved study. Each participant had their heart rate, core body temperature, and hydration status monitored during a 12-hour day-shift. Air temperature, relative humidity and apparent temperature were recorded every 30 minutes (Kestrel 4000, Kestrel Weather, Australia). Prior to the start of their shift a urine sample was collected and height and weight were measured. Heart rate was monitored by telemetry (Polar S625x, Polar, Kempele, Finland) and core body temperature by an ingestible temperature sensor (CorTemp, HQ inc, Palmetto FL, USA). All temperature sensors were calibrated following previously published procedures<sup>7</sup> and linear regression was used to correct raw data. Participants swallowed the sensors the night before, at least eight hours before monitoring commenced. Heart rate and core body temperature were recorded at one minute intervals. A urine sample was collected approximately half-way into the shift, and another immediately post-shift. Hydration status was assessed by measuring urine specific gravity (USG) (PAL-10s, ATAGO, Tokyo, Japan), with values  $\geq 1.020$  indicating dehydration<sup>2</sup>. Non-exercise predicted  $VO_{2max}$  was estimated from age, BMI, gender, and recreational physical activity<sup>11</sup>. Repeated measures ANOVA with pairwise comparisons was used to assess for differences in dependent variables across three time intervals (6 – 10am, 10 – 2pm, and 2 – 6pm).

## RESULTS



**Figure 1:** Percentage of workers experiencing each symptom of heat illness.

## Part A:

Figure one presents the percentage of respondents experiencing each symptom of heat illness. Eighty-seven percent reported experiencing at least one symptom of heat illness in the past 12 months, with an average of  $4.2 \pm 3.5$  symptoms per worker. Eighty-one percent of symptoms

were reported to have been experienced more than once. Due to the high proportion of workers experiencing symptoms of heat illness, it was not feasible to classify workers as either symptomatic or asymptomatic. Instead, workers reporting four out of the eight heat exhaustion symptoms (headache through to irritability), and / or three out of seven of the heat stroke symptoms (hot and dry skin through to convulsions), were classed as moderate heat illness, those not meeting this criteria were allocated to minor heat illness. Heat illness classification was not significantly related to age (minor:  $37.0 \pm 10.2$ , moderate:  $33.6 \pm 7.5$ ,  $t = 1.56$ ,  $p = 0.112$ ) or BMI (minor:  $28.1 \pm 3.6$ , moderate:  $27.6 \pm 4.2$ ,  $t = 0.527$ ,  $p = 0.599$ ). Heat illness classification was not related to time spent in recreational physical activity (minor: sedentary = 37 %, insufficient = 47 %, sufficient = 16 %; moderate: sedentary = 46 %, insufficient = 39 %, sufficient 15 %; Pearson chi-square 0.67,  $p = 0.715$ ), but was related to hydration status (minor: well hydrated = 34 %, minimal dehydration = 60 %, significant dehydration = 6.0 %; moderate: well hydrated = 16 %, minimal dehydration = 64 %, significant dehydration = 20 %; Pearson chi-square 5.74,  $p = 0.057$ ). Compared to well-hydrated workers, the relative risk of experiencing moderate symptoms of heat illness was 1.9 for minimal dehydration, and 3.7 for significantly dehydrated workers.

**Table 1:** Core temperature, heart rate, and urine specific gravity during the shift.

		6 am - 10 am	10 am - 2 pm	2 pm - 6 pm
<b>Average Core Temperature (°C)</b>	<i>Mean ± SD</i>	$37.37 \pm 0.20$	$37.42 \pm 0.17$	$37.57 \pm 0.19$ *
	<i>Range</i>	37.14 - 37.54	37.04 - 37.62	37.27 - 37.89
<b>Maximum Core Temperature (°C)</b>	<i>Mean ± SD</i>	$37.75 \pm 0.20$	$37.80 \pm 0.20$	$37.94 \pm 0.24$ *
	<i>Range</i>	37.32 - 37.99	37.39 - 38.19	37.50 - 38.44
<b>Average Heart Rate (bpm)</b>	<i>Mean ± SD</i>	$85.7 \pm 14.2$	$85.8 \pm 15.5$	$87.1 \pm 14.5$
	<i>Range</i>	60.7 - 114.6	59.8 - 120.3	63.4 - 120.1
<b>Maximum Heart Rate (bpm)</b>	<i>Mean ± SD</i>	$118.7 \pm 18.6$	$120.4 \pm 21.5$	$121.5 \pm 20.9$
	<i>Range</i>	79.0 - 145.0	81.0 - 157.0	90.0 - 157.0
<b>Urine Specific Gravity<sup>a</sup></b>	<i>Mean ± SD</i>	$1.023 \pm 0.007$	$1.023 \pm 0.007$	$1.024 \pm 0.007$
	<i>Range</i>	1.008 - 1.031	1.007 - 1.029	1.011 - 1.033

<sup>a</sup> 6 - 10 am urine samples collected pre-shift, 2 - 6 pm post-shift; \* Significantly different from 6 - 10am and 10 - 2pm ( $p < 0.05$ ).

#### Part B:

The 15 blast crew who participated were  $36.7 \pm 9.7$  years of age, had a BMI of  $31.0 \pm 4.5$  kg/m<sup>2</sup>, and a  $VO_{2max}$  of  $36.3 \pm 7.2$  ml/kg/min. Over the whole shift, average mean and maximum core body temperature was  $37.46 \pm 0.14$  °C and  $38.00 \pm 0.20$  °C respectively. The average change in core temperature over the course of the shift was  $1.05 \pm 0.22$  °C. Average mean and maximum heart rate was  $86.0 \pm 14.5$  bpm and  $126.9 \pm 19.9$  bpm respectively. Table 1 presents core body temperature, heart rate, and urine specific gravity during the shift, split into three time intervals. Core body temperature was significantly associated with time interval (average mean:  $F = 10.1$ ,  $p = 0.001$ ; average maximum  $F = 4.1$ ,  $p = 0.030$ ). Heart rate was not associated with time interval (average mean:  $F = 1.1$ ,  $p = 0.353$ ; average maximum  $F = 0.6$ ,  $p = 0.566$ ). Average USG values during the shift are also presented in table 1. A total of twelve urine samples were collected pre-

shift, 8 mid-shift, and 8 post-shift, only five participants collected a sample at all three time points – allowing for statistical analysis. USG was not associated with shift time interval ( $F = 0.9$ ,  $p = 0.435$ ). Mean USG was  $\geq 1.020$  for 83 %, 88%, and 88 % of pre, mid, and post-shift urine samples respectively. Climatic conditions changed significantly over the three time intervals (air temperature  $F = 74.7$ ,  $p = 0.000$ ; relative humidity  $F = 108.5$ ,  $p = 0.000$ , apparent temperature  $F = 24.0$ ,  $p = 0.001$ ) (table 2). Seventy-three percent of workers noted feeling thirsty during work, 60 % felt tired, 33 % weakness, 26 % light-headed, and 20 % for both cramps and nausea.

**Table 2:** Average and maximum climatic conditions across the shift.

	6am - 10am		10am - 2pm		2 pm - 6pm	
	Avg.	Max.	Avg.	Max.	Avg.	Max.
<b>Air Temperature (°C)</b>	28.6	33.0	33.9 *	37.9	35.5 *	40.6
<b>Relative Humidity (%)</b>	52.1	82.9	28.3 *	44.6	24.0 *#	56.3
<b>Apparent Temperature (°C)</b>	29.7	35.1	33.9 *	38.7	35.1 *	41.0

Avg. = average of mean values for each shift; Max. = maximum value recorded across all shifts; \* Significantly different from 6 - 10am ( $p < 0.05$ ); # Significantly different from 10 - 2 pm ( $p < 0.05$ ).

## CONCLUSIONS

Over 80 % of surface mine workers experienced symptoms of heat illness in a 12 month period, and the majority experienced symptoms on more than one occasion. The most commonly reported symptoms were fatigue, headache, perception of a high body temperature, and muscle cramp. Experiencing moderate symptoms of heat illness was not associated with age, BMI, or time spent in recreational physical activity. This is in contrast to previous research suggesting higher BMI<sup>5</sup> and lower aerobic fitness<sup>10</sup> to be risk factors for heat illness. A possible reason for this is that actual cases of heat illness (exhaustion or stroke) were not reported here, as in previous research. Workers in the forestry industry who reported symptoms of heat illness were significantly younger than those who did not<sup>9</sup>. Whilst those classified into the moderate heat illness category tended to be younger in the present study, the difference was insignificant. Experiencing symptoms of heat illness was associated with hydration status, with those reporting minimal or significant dehydration tending to report more symptoms. This finding coincides with research showing dehydration to be a risk factor for heat exhaustion<sup>6</sup>, and highlights a possible health and safety concern for surface mine workers.

The primary causes of heat illness are an excessive rise in core body temperature, becoming dehydrated, or a combination of both. Therefore these variables were monitored during a normal 12-hour shift for surface mine workers. Climatic conditions and work intensity were conducive to heat stress. The apparent temperature index of heat stress, accounting for both air temperature and humidity, showed a level of heat stress recommending “extreme caution” ( $AP \geq 32$  °C) in the later time intervals of the shift. Heart rate data shows a light intensity of physical work for

most of the shift, with short periods of moderate work, indicated by the higher maximum heart rates.

The Australian Institute of Occupational Hygienists recommends that core body temperature should not exceed 38.5 °C for medically selected and acclimatised personnel <sup>3</sup>. This limit was not exceeded by any of the workers studied. However, the average 1.05 °C change in core body temperature across the duration of the shift indicates that work in this environment does provide a challenge to thermoregulation. Access to air-conditioned break rooms was likely beneficial in keeping core body temperature within safe limits.

The most concerning finding of this investigation was that over 80 % of workers began work in a dehydrated state, and remained dehydrated for the duration of the shift. Dehydration is a concern as it decreases work capacity, and increases heat strain, the risk of accident and injury, and the risk of heat illness <sup>8</sup>. Symptoms of heat illness experienced during work were likely the result of dehydration, particularly because the most common symptom was thirst.

In conclusion, a large proportion of surface mine workers experience symptoms of heat illness. These are likely the result of poor hydration among the workforce. Strategies to improve hydration practices should be developed and implemented to reduce the risk of experiencing heat illness. In addition, further research is needed to document actual cases of heat illness.

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