Title: ***A seasonal comparison of a 14-day swing on cognitive function and psycho-physiological responses in mine service workers.***

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Abbreviations

HR	Heart rate
RH	Relative humidity
RPE	Rating of perceived exertion
T_c	Core temperature
USG	Urine specific gravity
WBGT	Wet bulb globe temperature

Abstract

This study assessed the effect of season on cognitive function and psycho-physiological responses during a 14-day swing in mine-service workers. Cognitive function, thermal sensation and comfort, rating of perceived exertion, fatigue, hydration, core temperature and heart rate were assessed throughout a shift, on three separate days over a swing. Working memory and processing efficiency did not differ between seasons ($p>0.05$), however counting and recall latencies improved throughout the swing ($p<0.05$). Participants reported greater fatigue post-shift compared to pre-shift ($p<0.05$). Thermal sensation, thermal comfort, and hydration were significantly elevated in summer compared to winter ($p<0.05$). Specifically, workers were significantly/minimally dehydrated in summer/winter (urinary specific gravity=1.025±0.007/1.018±0.007). Although cognitive function and thermal strain were not impaired in summer compared to winter, it is essential to reinforce worker's knowledge regarding hydration requirements. Additional education and/or incorporating scheduled rest breaks for hydration should be considered to ensure the health and safety of mine workers.

Key words: *thermal strain, dehydration, mining industry*

1.0 Introduction

Occupational heat exposure can have negative effects on worker safety due to potential impairment to cognitive function (Mazloumi et al., 2014) and increased thermal strain (Periard et al., 2021). These factors, alone or in combination, can lead to reduced productivity and an increased risk of injuries and heat-related illnesses (Varghese et al., 2019). Heat exposure at work can occur in both outdoor and indoor environments, or a combination of both (Jay & Brotherhood, 2016). Specifically, workers in industries such as mining, agriculture, and construction often spend significant time outdoors, resulting in prolonged exposure to hot ambient conditions. Meanwhile, workers in the hospitality sector, including chefs and cleaners, machinery operators, and even some surgeons, frequently work in hot indoor conditions (Palejwala et al., 2023, Pogačar, 2018, Venugopal et al., 2021). This can be due to exposure to radiant heat sources, such as stoves or machinery, or simply because they work in non-air-conditioned rooms with hot outdoor temperatures (Dang & Dowell, 2014). Furthermore, many of these workers are required to wear personal protective equipment, which can inhibit cooling and further increase the risk of heat strain (Payne et al., 1994).

Many mining sites in Australia frequently encounter hot conditions for many months of the year. Workers at these sites often spend one to four weeks on-site before returning home to more temperate environments for one to two weeks. In response to the challenging weather conditions, some outdoor mining workers can adjust their working pace accordingly. Conversely, other workers, such as service workers and cleaners, must complete a fixed amount of work daily, even when ambient temperatures are extreme. Remarkably, Australia currently lacks strict policies aimed at protecting workers from the adverse effects of working in extreme heat conditions.

The work regime followed by mine industry workers in Australia, involving flying to and from remote sites for weeks at a time, has prompted research into the effects of heat adaption on these workers (Taggart et al., 2023a). When exposed to consecutive days of hot-humid conditions, the body can acclimatise through physiological adaptations (Periard et al., 2021), including lower resting and exercise core temperature (T_c) and heart-rate (HR), increased sweat rate, and improved electrolyte balance (Sawka et al., 2011). Taggart et al. (2023a) assessed psycho-physiological parameters in outdoor mine workers during summer and winter swings to determine if workers adjusted to the heat in the summer months. No differences were found between seasons or over the swing for T_c, HR or perceptual ratings of thermal comfort, thermal sensation and rating of perceived exertion (RPE). Lack of difference in these variables may be attributed to the workers' ability to self-select their work intensity, thereby mitigating the effects of thermal stress (Sawka et al., 2011).

Previous mining studies have assessed either outdoor or underground workers during a single shift of their swing, or focused exclusively on work during the summer months, omitting a comparison with winter conditions (Hunt et al., 2014; Peiffer & Abbiss, 2013). For example, a recent study by Taggart et al. (2023b) compared the effects of working in hot ambient conditions on cognitive and psycho-physiological variables in outdoor mining workers compared to service workers. Service workers, who had fixed daily work schedules regardless of hot weather, exhibited higher HR and activity levels, and reported higher RPE, thermal discomfort and thermal sensation values. Notably, this study only reported average values and did not analyse workers during the winter season for comparison. To our knowledge, no research has assessed the effect of daily heat exposure throughout a 14-day swing in service workers (i.e., cleaners) in the mining industry, who work intermittently indoors and outdoors to a fixed daily schedule.

Therefore, this study aimed to investigate the effects of season on cognitive function and psycho-physiological responses over a 14-day swing in service workers who alternated between indoor and outdoor tasks. Firstly, we hypothesised that cognitive function, manual dexterity and fatigue levels would deteriorate over the course of a swing and shift, with changes more pronounced in summer. Secondly, we anticipated that thermal strain will worsen during a shift, and be worse at the start compared to end of a swing (in summer only), with changes more prominent in summer.

2.0 Methods

2.1 Participants

Twenty-six service workers (summer: male=5, female=7; winter: male=2, female=12) volunteered for this study. Descriptive statistics are provide in *Table 1*. Workers were fly-in fly-out employees who followed a 14-day work and 7-day home roster. Their work site was located in Port Hedland (Western Australia), and all participants resided within a 2-h radius of Perth during their 7-day break. Two workers participated in both summer and winter seasons. The participants' main role on-site was to clean and maintain rooms in which other personnel resided during their swing. Their tasks included carrying loads of varying weight, pushing trolleys, making beds, delivering linen, cleaning bathrooms, mopping, walking, and other cleaning tasks. Workers moved intermittently between indoor and outdoor environments, spending approximately two-thirds of the workday indoors (in non-air-conditioned areas) and the remaining one-third outdoors (*Table 2*). Workers had daily cleaning quotas to meet within the mine site village. Participants were informed of the study requirements before providing their informed written consent. Ethics approval was granted by the Human Research Ethics Committee of the University of Western Australia (RA/4/20/6536).

Table 1. Demographic information of service workers in summer (n=12) and winter (n=14) (mean ±SD).

	Age (y)	Height (m)	Weight (kg)	BMI	Employment (y)	Male (n)	Female (n)
Summer	40±14	1.70±0.08	78.3±13.2	27.1±3.9	1.2±1.8	5	7
Winter	31±9	1.67±0.09	70.0±10.7	25.2±3.7	0.8±1.1	2	12

Note: no significant differences between summer and winter for any variable. Sex was excluded from the analysis.

2.2 Study design

Workers' cognitive function, manual dexterity, fatigue and psycho-physiological responses were assessed throughout a 12-h shift at three points during their 14-day swing, during summer (February/March 2022) and winter (June 2022). Recruitment and familiarisation took place on the first day of their swing, with testing occurring on day 2 or 3, day 8 or 9, and day 13 or 14 of their 14-day swing. All workers were allowed ~15 min for both a morning and afternoon break, in addition to a 60-min lunch break. Towards the end of the swing, the number of service workers decreased, as four (summer) and two (winter) workers unexpectedly left the site early. Workers wore long-sleeve highvisibility shirts, trousers, steel-cap boots, and a hat. Gloves were worn while conducting cleaning tasks. A food and fluid consumption diary was completed during each shift.

2.3 Familiarisation session

Participants' anthropometric data and demographic information were recorded (*Table 1*). Workers were then introduced to the T_c pills and HR monitors and familiarised with the fatigue questionnaire and perceptual scales. Finally, they performed five trials of the cognitive function (counting span) and manual dexterity (Purdue pegboard) tasks to reduce any potential learning effects (Saldaris et al., 2019).

2.4 Protocol

Before the start of their shift, participants were fitted with a HR monitor and ActiGraph. Within a 30-min period before starting their shift, they provided a urine sample. Workers then attended a ~25 min meeting where their daily tasks were outlined. After this, workers completed cognitive function and manual dexterity tasks, and filled out a fatigue questionnaire. Core temperature, HR, thermal comfort, RPE, and thermal sensation were all recorded. Throughout the shift, T_c, HR, and perceptual measures were recorded at five time points (7 am, 10 am, 1 pm, 4 pm, and 7 pm). Cognitive function, urine specific gravity (USG), and fatigue were assessed only pre- and post-shift. The analysis included only peak values for T_c, HR, and perceptual measures. Pre- and post-shift testing was conducted outdoors in a seated position, with task order replicated for each participant. Outdoor temperature (ambient temperature, wet bulb globe temperature (WBGT), globe temperature, relative humidity) was monitored hourly throughout the testing day. Indoor temperature was recorded during 16 different room cleans at ~5-min intervals (room entry, mid-clean, and room exit) via the QuesTEMP 32 (TSI Incorporated, USA; accuracy ± 0.5˚C). Outdoor wind speed was measured at hourly intervals via a digital anemometer (Model : AM-4203HA, Lutron Electronic Enterprise Co., LTD., Taiwan; accuracy 0.1 ± km/h).

2.5 Physiological responses

Core temperature was continuously monitored by an ingestible radio-telemetric capsule, which participants ingested 6-8 h prior to the start of work (CorTemp HQ Inc., Palmetto, USA; accuracy±0.1˚C). Heart rate was measured continuously via a chest-based monitor (Polar H7, Finland). Activity levels were recorded using an Actigraph worn on the hip, which measured step counts (Actigraph GT3X, Pensacola, USA). Hydration status was quantified using USG, measured from a urine sample using a handheld refractometer (ATAGO Model URC-N_E, Japan). Classifications were as follows: *well hydrated* <1.010, *minimal dehydration* 1.010-1.020, *significant dehydration* 1.021-1.030 and *serious dehydration* >1.030 (Casa et al., 2000).

2.6 Perceptual responses

The Borg scale (Borg, 1982) was used to measure RPE (6 [no exertion at all] to 20 [maximal exertion]). Thermal comfort (0 [very comfortable] to 20 [very uncomfortable]) and thermal sensation (0 [very cold] to 20 [very hot]) were recorded with visual analogue scales, ranging from white to back and green to red, respectively (Gaoua et al., 2012).

2.7 Fatigue

Perceived fatigue was measured using the Multidimensional Fatigue Scale, encompassing physical, mental and general fatigue, as well as motivation and activity. It has been previously validated in army recruits and junior doctors (Barclay et al., 2013; Smets et al., 1995). Higher scores represented greater levels of fatigue, with the scale ranging from 1 (Yes, this is true) to 5 (No, this is not true).

2.8 Cognitive function and manual dexterity

Two domains of cognitive function—processing efficiency and working memory—were assessed using a modified version of the counting span task (Conway et al., 2005; Inquisit Lab 6, Millisecond Software, Seattle, USA). The task took ~5 min to complete and required participants to count the green dots on a sequence of cards containing yellow and green dots. Participants recalled the counts in order, with set size increasing from 2 to 7. Counting latency, first recall latency, subsequent recall latency, number of cards counted correctly, number of cards recalled correctly, and counting span (largest set size correctly recalled) were recorded (Taggart et al., 2023c). Individual latencies (ms) were aggregated across all trials. The Purdue Pegboard was used to assess manual dexterity skills (i.e., concentration, hand-eye coordination, and fine motor skills; Model 32020, J.A Preston Corporation, New York). The task took ~2 min to complete.

2.9 Statistical analysis

Data was expressed as mean ± standard deviation. Statistical analysis was conducted using R studio 1.4.1717. A linear mixed model analysis was used to analyse environmental data between summer and winter for both outdoor and indoor temperature. Linear mixed model analysis was used to compare peak shift values for T_c, HR, thermal sensation, RPE, and thermal comfort, with season and swing included as fixed effects and participants as a random effect. For cognitive function, manual dexterity, fatigue, and USG, a linear mixed model analysis was used with season, swing, and shift included as fixed effects and participants as a random effect. Cohen's *d* effect sizes were calculated for primary variables, however no moderate (*0.50-0.79*) to large (*>0.80*) effect sizes were found.

3.0 Results

Ambient temperature, globe temperature, relative humidity, and wind speed ($p<0.05$) were all significantly higher in summer (outdoors) compared to winter (outdoors) (*Table 2*). Summer (outdoor) ambient and globe temperatures were significantly greater than those during summer (indoor) and winter (indoor) conditions ($p<0.05$).

Table 2. Environmental conditions indoors and outdoors in summer (n=25) and winter (n=23).

	Ambient temperature (°C)	Globe temperature (°C)	WBGT °C	Relative humidity (%)	Wind speed (km/h)
Summer (outdoor)	35.3±4.5	43.9±9.1	31.0±3.0	46±21	6.5±5.3
Summer (indoor)	29.5±3.4[a]	28.8±3.3[a]	23.3±2.4	46±8	
Winter (outdoor)	26.2±4.7[a]	31.9±9.8[a]	20.4±3.0	38±19[a]	3.2±2.9[a]
Winter (indoor)	24.7±1.8[ab]	24.6±2.1[ac]	18.5±1.3	40±11	

[a], significantly different from summer (outdoor)

[b], significantly different to summer (indoor)

[c], significantly different to winter (outdoor)

3.1 Processing efficiency

Cognitive processing efficiency was assessed via counting performance on the counting span task. For correct counting responses, there was no significant main effect of season, swing, or shift, nor were there any interaction effects ($p \geq 0.106$). For counting latency, there was a significant main effect for swing, shift, and the number of target dots ($p<0.05$), but not for season (*Figure 1*; $p=0.787$). These main effects were qualified by three significant interaction effects: swing and shift ($p=0.040$), swing and target dots ($p<0.001$), and shift and target dots ($p=0.044$). These indicated that latencies were longer pre-shift compared to post-shift at both the start ($p<0.001$) and end ($p=0.043$) of a swing, but not the middle ($p=0.234$), and especially for cards with a higher number of target dots to be counted.

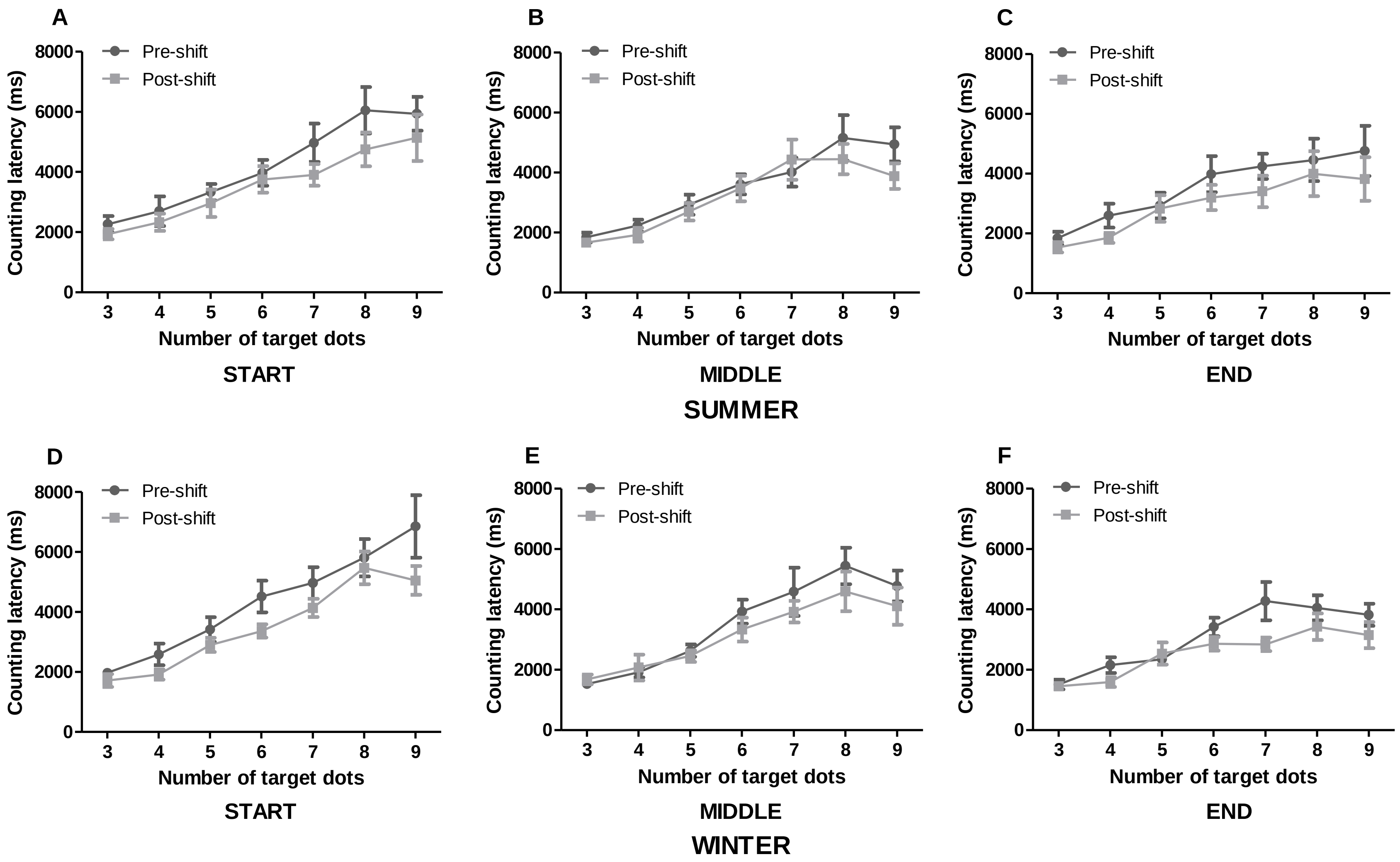

Figure 1. Counting latency in summer (A-C) and winter (D-F) over the course of a shift

3.2 Working memory

There was a significant main effect of swing ($p<0.001$), but not season ($p\geq0.362$) or shift ($p\geq0.067$) for both first and subsequent response recall latency (*Table 3*). Recall latency was slower at the start of the swing compared to the middle ($p\leq0.010$) and end ($p\leq0.001$). There was no significant interaction effect for either first or subsequent recall latency ($p\geq0.080$).

There was no significant main effect of season, swing, or shift, nor was there any interaction effects for correct recall responses or counting span scores ($p\geq0.065$). The mean counting span score in summer was 5.4±1.1 and in winter 5.2±1.3.

Table 3. First and subsequent response recall latency scores (ms) over the swing between seasons.

	Summer			**Winter**		
	Start of swing	**Middle of swing**	**End of swing**	**Start of swing**	**Middle of swing**	**End of swing**
First response recall latency (ms)	2163±666	1957±584	1888±567	1975±542	1767±415	1757±565
Subsequent response recall latency (ms)	1437±1032	1129±657	1110±989	1430±1748	1080±819	902±418

3.3 Manual dexterity

There was no main effect of season or swing for either the dominant or non-dominant hand ($p\geq0.084$). There was a significant main effect of shift for both the dominant and non-dominant hand, whereby performance was better post-shift compared to pre-shift ($p\leq0.043$). There were no interaction effects between season, swing, or shift for either hand ($p\geq0.181$).

3.4 Fatigue and mental health

There was a significant main effect of shift for all domains of fatigue ($p<0.05$), where participants felt greater fatigue, reduced motivation, and activity post-shift compared to pre-shift (*Table 4*). There was a significant main effect of season for mental fatigue ($p=0.023$), where participants were more mentally fatigued in winter compared to summer. There was no main effect of swing nor any interaction effects for any domain of fatigue ($p>0.05$).

Depression, anxiety, and stress did not show a significant main effect for season or swing, nor were there any significant interaction effects ($p \geq 0.418$). Mean scores for depression (5±5), anxiety (7±5), and stress (10±6) were all categorised as normal.

Table 4. Fatigue scores for each domain at the start, middle, and end of a swing.

	General fatigue*		Physical fatigue*		Mental fatigue*#		Reduced motivation*		Reduced activity*	
	Pre-shift	**Post-shift**	**Pre-shift**	**Post-shift**	**Pre-shift**	**Post-shift**	**Pre-shift**	**Post-shift**	**Pre-shift**	**Post-shift**
Summer (n)										
Start of swing (12)	10±3	13±3	9±2	10±3	9±2	10±2	8±3	11±4	8±2	9±2
Middle of swing (12)	10±3	12±3	7±2	9±3	10±2	10±3	9±3	10±4	8±3	8±3
End of swing (9)	8±3	11±4	7±2	10±4	8±2	11±4	7±3	10±4	7±2	9±3
Winter (n)										
Start of swing (14)	9±3	12±3	8±3	10±3	11±3	13±4	9±3	12±3	8±2	9±3
Middle of swing (14)	9±3	11±3	7±3	10±4	11±4	12±3	9±3	12±3	7±2	8±3
End of swing (12)	11±4	11±3	8±4	10±4	12±4	13±3	10±3	12±2	9±4	8±2

*, significant main effect for shift ($p<0.05$)

#, significant main effect for season ($p=0.023$)

3.5 Physiological responses

There was no significant main effect for season ($p \geq 0.945$) or swing ($p \geq 0.401$) for HR or T_c, nor was there an interaction effect (*Figure 2*; $p \geq 0.450$). Peak HR was 106±14 bpm and 106±9 bpm and T_c was 37.82±0.22°C and 37.84±0.34°C, in summer and winter, respectively.

There was a significant main effect of season for USG, with participants more dehydrated in summer (1.025±0.007) compared to winter (1.018±0.007; *Table 5;* $p=0.010$). There was no main effect of swing ($p=0.256$) or shift ($p=0.272$), nor was there an interaction effect ($p \geq 0.094$). Water intake in summer (3.6±1.2 L) was significantly greater than winter (2.3±1.0 L; $p=0.003$). There was no main effect of swing ($p=0.540$) or interaction effect ($p=0.180$).

Table 5. Urinary specific gravity classifications in summer and winter throughout the swing.

	< 1.010 *"well hydrated"*		1.010-1.020 *"minimal dehydration"*		1.021-1.030 *"significant dehydration"*		> 1.030 *"serious dehydration"*	
	Pre-shift	**Post-shift**	**Pre-shift**	**Post-shift**	**Pre-shift**	**Post-shift**	**Pre-shift**	**Post-shift**
Summer#								
Start of swing		1	3	1	6	6	3	4
Middle of swing		1	5	2	7	6		3
End of swing	1				7	6		2
Winter								
Start of swing		2	10	5	4	7		
Middle of swing	1	2	9	6	4	6		
End of swing	3	3	4	6	5	2		1

#, significant main effect for season (p=0.012)

There was no significant main effect of season ($p=0.388$) or swing ($p=0.680$) for activity (steps), nor was there an interaction effect ($p=0.451$). Average steps in summer were 11,171±1,878 and winter 11,866±2,277.

3.6 Perceptual responses

Both thermal sensation and thermal comfort showed a significant main effect for season ($p\leq0.001$), while neither had a significant main effect for swing (*Figure 2*; $p\geq0.052$). Ratings of perceived exertion did not exhibit a significant main effect of season or swing ($p\geq0.054$). There were no significant interaction effects between season and swing for any of the perceptual variables.

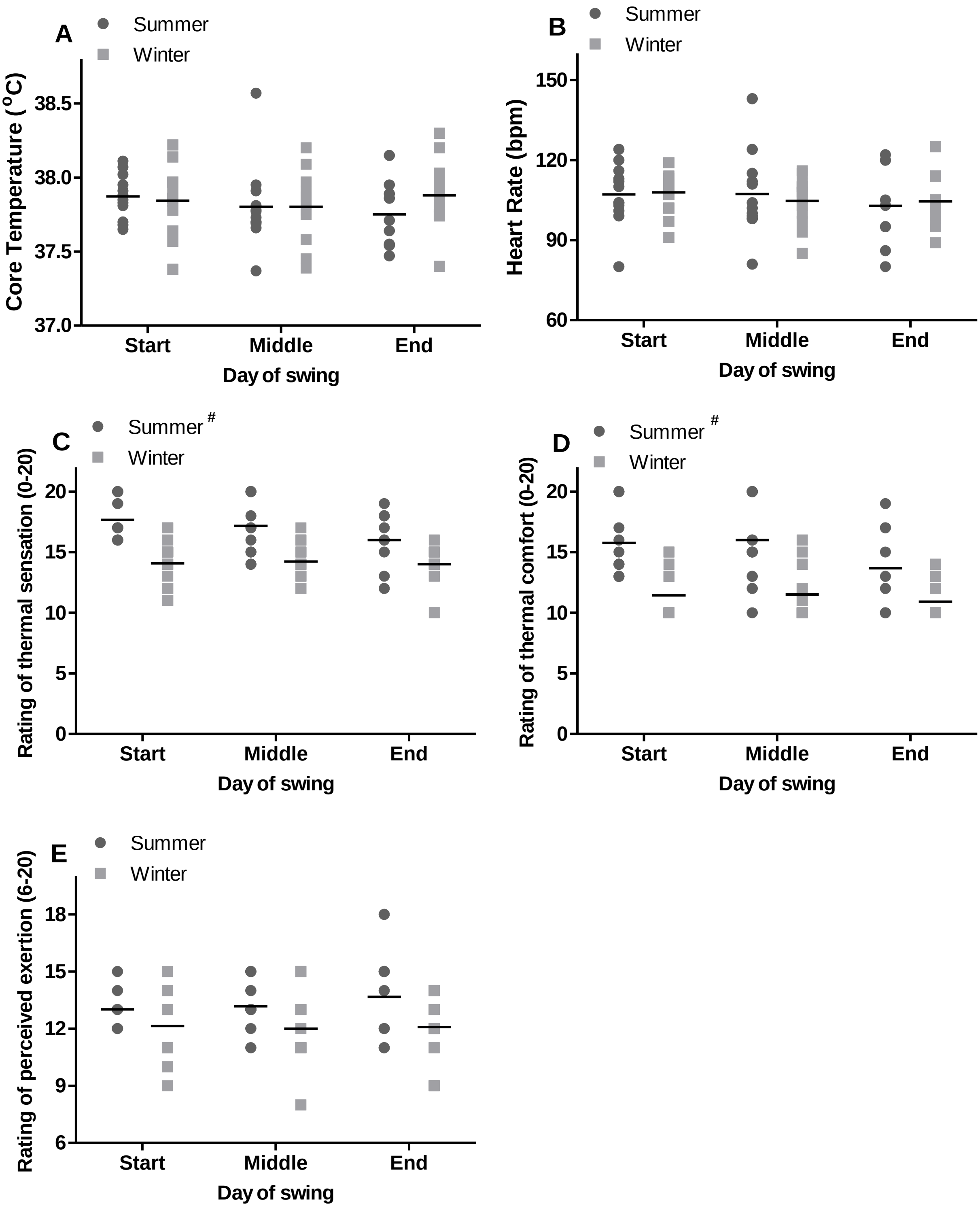

Figure 2. Peak core temperature (A), heart rate (B), thermal sensation (C), thermal comfort (D) and rating of perceived exertion (E) over the course of a swing between seasons.

#, significant main effect of season ($p<0.05$)

4.0 Discussion

This study aimed to assess cognitive function, fatigue, and psycho-physiological responses in mine service workers during 14-day swings in summer and winter. Contrary to our first hypothesis, cognitive function and fatigue (except for mental fatigue) were not significantly different in summer compared to winter. Regarding the effects of swing itself, both counting and recall (first and subsequent) latency significantly improved over the course of a swing. However, no differences were observed in any domain of fatigue, or physiological and perceptual variables, which did not support our initial hypotheses. Core temperature, HR, and RPE did not differ between seasons, however, summer did result in worse dehydration and increased thermal discomfort and sensation, partially supporting our second hypothesis. Overall, despite the higher environmental temperatures both indoors and outdoors in summer compared to winter, our study did not reveal any cognitive decrements or physiological adaptations attributable to occupational heat exposure.

4.1 Cognitive function

The lack of significant differences in processing efficiency and working memory between seasons was unexpected and contradicts the findings of Mazloumi et al. (2014). These authors reported a decline in cognitive function in participants exposed to occupational heat (32.9°C WBGT), compared to a control group in cooler conditions (16.8°C WBGT). Similarly, Gaoua et al. (2018) reported decrements in working memory performance after passive heat exposure. However, it is worth noting that the ambient temperature (50°C, 50% RH) and T_c levels (39.1°C) in their study were considerably higher than those recorded here. The absence of a difference in cognitive function between seasons in our study may be attributed to the lower-than-expected T_c, HR, and fatigue values recorded for summer. Previous research has found that when T_c remains below 38.5°C (hyperthermia), complex cognitive function, such as executive function and working memory, was unchanged (Girard et al., 2021). Additionally, the reduction in solar radiation exposure from working mainly indoors may have contributed to the preservation of cognitive function due to a reduction in thermal stress. As this is the first study to assess the effects of prolonged heat exposure on service workers with a fixed daily schedule, we recommend further research to explore the effects of prolonged heat exposure on other cognitive domains, such as executive function, attention, and verbal reasoning.

Another unexpected finding was the improvement in both counting and recall latency over the course of a swing. Although speculative, the improvement over the course of the swing may be due to the initial adjustment to the work routine after returning from a break. Individuals might experience slower processing speed and reduced attention at the start of the swing, particularly when adjusting to early morning wake-up schedules and a new sleeping environment (Asare et al., 2022). Another explanation is a learning effect, since participants completed the cognitive task nine times over the course of a swing, this repetition could have contributed to improved performance (Tao et al., 2019). To address this possibility, workers underwent familiarisation including five practice trials, with a random sequence of numbers each time they completed the task; however, we cannot exclude this possibility entirely.

4.2 Hydration

One important observation was that workers were significantly more dehydrated in summer compared to winter. Despite no difference in T_c, HR, or activity during summer compared to winter, it is likely that workers performing similar physical tasks at a consistent work rate in both seasons had a greater sweat rate during summer so to thermoregulate efficiently (Sawka et al., 1993). Increased sweating, if not compensated by sufficient water intake, can result in greater dehydration levels (Kenefick, 2018). Despite greater water intake in summer, this was insufficient to keep workers adequately hydrated. Importantly, dehydration can lead to impairment in cognitive function (Ganio et al., 2011), compromised thermoregulatory function (Sawka et al., 1993), and increased risk of kidney disease (Chapman et al., 2021). Future research should aim to measure sweat loss and rate in fixed-schedule workers in the field, enabling the development of recommendations for fluid requirements to safeguard the health and safety of workers.

4.3 Fatigue

Four of five domains of perceived fatigue did not show differences between seasons, and no domains of fatigue exhibited differences throughout the swing. This result was unexpected as thermal discomfort and thermal sensation were significantly greater in summer compared to winter. A previous study reported that perceived fatigue is greater when working in the heat (Palejwala et al., 2023). However, results here are supported by Taggart et al. (2023a) and McLaughlin et al. (2008), who found no differences in perceived fatigue between summer and winter in outdoor workers and shift-workers, respectively. This lack of difference in perceived fatigue might be attributed to testing different participants between seasons, leading to variations in how individuals perceive their fatigue levels. Unexpectedly, mental fatigue was greater in winter compared to summer. One potential explanation could be seasonal affective disorder, where reduced sunlight hours in winter can lead to seasonal dysphoria (Melrose, 2015). However, this explanation remains speculative, as results from the depression, anxiety, and stress scale did not reveal differences between seasons, thus not supporting this explanation.

4.4 Limitations

This study did not measure skin temperature or sweat loss throughout the shift, nor did it include a heat tolerance test. These physiological responses would have provided valuable insights into how workers adapted or acclimatised to the heat over the course of a swing. Participants in this study were assessed in February/March (i.e., the end of the Australian summer), which may have influenced the seasonality response, as participants may have already been partially adapted to the hot working environment. Research assessing workers when they are not acclimatised (November/December) is required to assess how workers respond to heat stress at the beginning of a season, with comparison to the end of a season.

5.0 Conclusion

In summary, cognitive function and thermal strain over the course of a 14-day swing in mine service workers were assessed for the first time. Cognitive impairment and thermal strain were not experienced despite working in the heat. However, dehydration was more prevalent in summer compared to winter, with thermal discomfort and thermal sensation both higher in summer. These results suggest that thermoregulation was sufficient in these workers, however that workers may require further rest breaks or education around fluid intake during a work shift in the heat. Future research should consider the current education provided to workers regarding hydration requirements when working in the heat on Australian mining sites, with the aim to establish standards to ensure workers are adequately hydrated, thereby safeguarding their health against issues associated with dehydration.

Research Ethics Approval

Ethics approval was granted by the Human Research Ethics Committee of the University of Western Australia (RA/4/20/6536).

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Conflict of interest

The authors report no conflict of interest**.**

References

Asare, B. Y.-A., Robinson, S., Powell, D., & Kwasnicka, D. (2022). Health and related behaviours of fly-in fly-out workers in the mining industry in Australia: a cross-sectional study. *International Archives of Occupational and Environmental Health*, 1-16.

Barclay, M., Harris, J., Everingham, J., Kirsch, P., Arend, S., Shi, S., & Kim, J. (2013). *Factors linked to the well-being of fly-in fly-out (FIFO) workers*. The Centre for Social Responsibility in Mining and Minerals Industry Safety and Health Centre. https://www.csrm.uq.edu.au/publications/factors-linked-to-the-well-being-of-fly-in-fly-out-fifo-workers

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, *14*(5), 377-381. https://doi.org/https://doi.org/10.1249/00005768-198205000-00012

Casa, D. J., Armstrong, L. E., Hillman, S. K., Montain, S. J., Reiff, R. V., Rich, B., Roberts, W. O., & Stone, J. A. (2000). National Athletic Trainers' Association position statement: fluid replacement for athletes. *Journal of Athletic Training*, *35*(2), 212.

Chapman, C. L., Johnson, B. D., Parker, M. D., Hostler, D., Pryor, R. R., & Schlader, Z. (2021). Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. *Temperature*, *8*(2), 108-159.

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769-786. https://doi.org/10.3758/BF03196772

Dang, B. N., & Dowell, C. H. (2014). Factors associated with heat strain among workers at an aluminum smelter in Texas. *Journal of Occupational and Environmental Medicine*, *56*(3), 313.

Ganio, M. S., Armstrong, L. E., Casa, D. J., McDermott, B. P., Lee, E. C., Yamamoto, L. M., Marzano, S., Lopez, R. M., Jimenez, L., & Le Bellego, L. (2011). Mild dehydration impairs cognitive performance and mood of men. *British Journal of Nutrition*, *106*(10), 1535-1543.

Gaoua, N., Grantham, J., Racinais, S., & El Massioui, F. (2012). Sensory displeasure reduces complex cognitive performance in the heat. *Journal of Environmental Psychology*, *32*(2), 158-163. https://doi.org/10.1016/j.jenvp.2012.01.002

Gaoua, N., Herrera, C. P., Périard, J. D., El Massioui, F., & Racinais, S. (2018). Effect of passive hyperthermia on working memory resources during simple and complex cognitive tasks. *Frontiers in Psychology*, *8*, 2290.

Girard, O., Gaoua, N., Grantham, J., Knez, W., Walsh, A., & Racinais, S. (2021). Effects of living and working in a hot environment on cognitive function in a quiet and temperature-controlled room: An oil and gas industry study. *Temperature*, *8*(4), 1-9. https://doi.org/https://doi.org/10.1080/23328940.2021.1959289

Hunt, A. P., Parker, A. W., & Stewart, I. B. (2014). Heat strain and hydration status of surface mine blast crew workers. *Journal of Occupational and Environmental Medicine*, *56*(4), 409-414. https://doi.org/10.1097/JOM.0000000000000114

Jay, O., & Brotherhood, J. R. (2016). Occupational heat stress in Australian workplaces. *Temperature*, *3*(3), 394-411.

Kenefick, R. W. (2018). Drinking strategies: planned drinking versus drinking to thirst. *Sports Medicine*, *48*(Suppl 1), 31-37.

Mazloumi, A., Golbabaei, F., Khani, S. M., Kazemi, Z., Hosseini, M., Abbasinia, M., & Dehghan, S. F. (2014). Evaluating effects of heat stress on cognitive function among workers in a hot industry. *Health Promotion Perspectives*, *4*(2), 240-246. https://doi.org/10.5681/hpp.2014.031

McLaughlin, C., Bowman, M. L., Bradley, C. L., & Mistlberger, R. E. (2008). A prospective study of seasonal variation in shift-work tolerance. *Chronobiology International*, *25*(2-3), 455-470.

Melrose, S. (2015). Seasonal affective disorder: an overview of assessment and treatment approaches. *Depression Research and Treatment*, *2015*(1), 1-6. https://doi.org/10.1155/2015/178564

Palejwala, Z., Wallman, K. E., Maloney, S., Landers, G. J., Ecker, U. K. H., Fear, M. W., & Wood, F. M. (2023). Higher operating theatre temperature during burn surgery increases physiological heat strain, subjective workload, and fatigue of surgical staff. *PLoS One*, *18*(6), e0286746.

Palejwala, Z., Wallman, K. E., Maloney, S., Landers, G. J., Ecker, U. K. H., Fear, M. W., & Wood, F. M. (2023). Higher operating theatre temperature during burn surgery increases physiological heat strain, subjective workload, and fatigue of surgical staff. *PLoS One*, *18*(6), e0286746. https://doi.org/10.1371/journal.pone.0286746

Payne, W. R., Portier, B., Fairweather, I., Zhou, S., & Snow, R. (1994). Thermoregulatory response to wearing encapsulated protective clothing during simulated work in various thermal environments. *American Industrial Hygiene Association Journal*, *55*(6), 529-536.

Peiffer, J. J., & Abbiss, C. R. (2013). Thermal stress in North Western Australian iron ore mining staff. *The Annals of Occupational Hygiene*, *57*(4), 519-527. https://doi.org/10.1093/annhyg/mes084

Periard, J. D., Eijsvogels, T. M. H., & Daanen, H. A. M. (2021). Exercise under heat stress: thermoregulation, hydration, performance implications and mitigation strategies. *Physiological Reviews*, *101*(4), 1873-1979. https://doi.org/https://doi.org/10.1152/physrev.00038.2020

Pogačar, T., Casanueva, A., Kozjek, K., Ciuha, U., Mekjavić, I. B., Kajfež Bogataj, L., & Črepinšek, Z. (2018). The effect of hot days on occupational heat stress in the manufacturing industry: implications for workers' well-being and productivity. *International Journal of Biometeorology*, *62*, 1251-1264. https://doi.org/10.1007/s00484-018-1530-6

Saldaris, J. M., Landers, G. J., & Lay, B. S. (2019). Enhanced decision making and working memory during exercise in the heat with crushed ice ingestion. *International Journal of Sports Physiology and Performance*, *15*(4), 503-510. https://doi.org/10.1123/ijspp.2019-0234

Sawka, M. N., Leon, L. R., Montain, S. J., & Sonna, L. A. (2011). Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. *Comprehensive Physiology*, *1*(4), 1883-1928. https://doi.org/10.1002/cphy.c100082

Sawka, M. N., Wenger, C. B., Young, A. J., & Pandolf, K. B. (1993). *Physiological responses to exercise in the heat*.

Smets, E. M., Garssen, B., Bonke, B., & Haes, J. C. D. (1995). The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. *Journal of Psychosomatic Research*, *39*(3), 315-325. https://doi.org/10.1016/0022-3999(94)00125-o

Taggart, S. M., Girard, O., Landers, G. J., Ecker, U. K., & Wallman, K. E. (2023a). Impact of living and working in the heat on cognitive and psycho-physiological responses in outdoor fly-in fly-out tradesmen: a mining industry study. *Frontiers in Physiology*, *14*. https://doi.org/10.3389/fphys.2023.1210692

Taggart, S. M., Girard, O., Landers, G. J., Ecker, U. K. H., & Wallman, K. E. (2023b). Comparing thermal strain in outdoor maintenance and indoor service workers in the mining industry during summer. *PLoS One*, *18*(10), e0292436.

Taggart, S. M., Girard, O., Landers, G. J., Ecker, U. K. H., & Wallman, K. E. (2023c). Seasonal influence on cognitive and psycho-physiological responses to a single 11-h day of work in outdoor mine industry workers. *Temperature*, 1-14. https://doi.org/10.1080/23328940.2023.2208516

Tao, M., Yang, D., & Liu, W. (2019). Learning effect and its prediction for cognitive tests used in studies on indoor environmental quality. *Energy and Buildings*, *197*, 87-98. https://doi.org/https://doi.org/10.1016/j.enbuild.2019.05.044

Varghese, B. M., Barnett, A. G., Hansen, A. L., Bi, P., Hanson-Easey, S., Heyworth, J. S., Sim, M. R., & Pisaniello, D. L. (2019). The effects of ambient temperatures on the risk of work-related injuries and illnesses: Evidence from Adelaide, Australia 2003–2013. Environmental Research, 170, 101-109. https://doi.org/10.1016/j.envres.2018.12.024

Venugopal, V., Latha, P. K., & Shanmugam, R. (2021). O-371 Occupational heat exposures and renal health implications – A cross-sectional study among commercial kitchen workers in south india. *Occupational and Environmental Medicine, 78,* A22. https://doi.org/10.1136/OEM-2021-EPI.57