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Heat Stress Exposure and Chronic Kidney Disease in Indonesian Rayon Factory Workers

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Abstract

Chronic kidney disease (CKD) has become an emerging occupational health concern, particularly among workers exposed to high temperatures. This study aimed to determine the prevalence of CKD among workers in a rayon factory in West Java, Indonesia, and evaluate its association with occupational heat exposure. A retrospective cohort study was conducted using secondary data from the company's annual medical check-up records (2022–2023) and workplace heat stress measurements obtained in 2017 using the Quest Temp Wet-Bulb Globe Temperature monitor. Workers who completed medical examinations in both years and gave written informed consent to participate in the study were included. CKD was defined as a serum creatinine level >1.2 mg/dL and an estimated glomerular filtration rate <60 mL/min/1.73 m^2 in two consecutive years. Chi-square tests were used for bivariate analysis, and multivariate logistic regression was performed to obtain adjusted odds ratios (ORs). Of 675 eligible workers, male constituted the majority (99.7%) and 49% were older than 40 years. Most workers (96.1%) were exposed to workplace temperatures above 28°C, and obesity (47%), hypertension (16.7%), and diabetes mellitus (5.5%) were common comorbidities. The prevalence of reduced kidney function was 5.5%, with heat exposure of 28.2–30°C associated with an OR of 4.5 (95% CI: 1.372–14.792). The prevalence of CKD was 0.9%, and heat exposure in the same temperature range demonstrated an OR of 8.958 (95% CI: 1.207–66.515). However, the association was not statistically significant after adjusting for age, obesity, and hypertension. These findings suggest that occupational heat exposure may contribute to early kidney impairment, highlighting the need for heat mitigation strategies and routine worker health monitoring in industries where workers are at risk of heat exposure.

Keywords: Chronic kidney diseases, heat stress, Indonesia, workers

Introduction

Health Social Security Administering Agency (BPJS Health) of Indonesia reported that over the past five years, chronic kidney disease (CKD) has ranked among the top four catastrophic diseases incurring the highest healthcare costs for BPJS Health Indonesia. In 2022, CKD had the second highest number of visits, totalling 1,322,798 cases and costing 2,156 trillion IDR. [1]

The 2018 Basic Health Research (Riskesdas) in Indonesia indicated a CKD prevalence of 0.38%. This study also highlighted that the highest proportion of CKD cases was found in the 65–74 year age group (0.82%), while the lowest was in the 15–24 year age group (0.13%). However, given the large population of the 15–24 year age group, the weighted number of CKD sufferers in this group was the highest, with 159,015 individuals affected.[2] This data underscores the significant impact of CKD on the young age group, which is typically considered to be in their most productive years as workers or students.

Heat stress is a well-known occupational health concern, with heavy labour under extreme heat conditions being linked to several illnesses and premature deaths. Numerous studies from different countries have explored the impact of heat stress on CKD [3–9] and reduced kidney function among the indoor factories.[10] Heat stress contributes to CKD through multiple interrelated pathways, including dehydration-induced ischemia, oxidative stress, andand

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inflammation.[7,11] However, CKD caused by heat stress, commonly seen in outdoor workers in hot climates, is primarily linked to recurrent dehydration. The pathophysiology involves heat stress triggering dehydration, which reduces blood flow to the kidneys that contribute to repeated episodes of decreased kidney perfusion and acute kidney injury, which, over time, can progress to CKD.[12]

Research on the impact of heat stress on kidney health among indoor workers remains limited in Indonesia. Although diabetes mellitus and hypertension are widely recognized as the primary risk factors for CKD, there is a need for more comprehensive studies on other risk factors, such as chronic dehydration, high workplace temperatures, exposure to chemicals, and additional occupational hazards.[13,14] Such research is essential for developing protective measures for workers.

Several studies in Indonesia reported a higher prevalence of CKD among workers compared to Riskesdas data.[15–18] A study among farmers in West Java reported that the prevalence of CKD was 24.9%,[15] while another study among the population indicated the prevalence of CKD was 0.5%.[16] A literature review regarding CKD prevalence across Asia reported that CKD prevalence in Indonesia was 8.6 (7.2 to 10.0), and for advanced CKD was 1.5 (0.9 to 2.1).[17] There is a massive gap in the prevalence of CKD among the studies that the difference in the population can cause. First, there is substantial variability in the etiological spectrum of CKD. Second, it is observed substantial variability in the study inclusion criteria, including age, sex, data collection methods, and definitions used to define CKD across the region.[17,19]

The present study provides two key novel contributions. First, it distinguishes between reduced kidney function and established CKD, addressing inconsistencies in case definitions that have complicated interpretation of prior studies. Second, it incorporates serum creatinine and estimated glomerular filtration rate (eGFR) measurements obtained over two consecutive years, allowing confirmation that kidney function abnormalities persisted for more than one year an essential requirement for diagnosing CKD. This methodological approach strengthens the accuracy of CKD classification and enhances the validity of the findings.

This study aims to determine the prevalence of CKD among indoor workers exposed to occupational heat stress and to identify associated risk factors. The machinery and equipment used in some industries emit significant amounts of heat, contributing to elevated workplace temperatures. The findings are expected to serve as a reference for implementing further preventive measures for workers exposed to heat stress and other risk factors of CKD.

Methods

This study utilized a retrospective cohort design and was conducted between February and June 2024 at a rayon industry in West Java, Indonesia. Rayon production involves several high-temperature processes, including spinning, drying, and chemical treatment.

The company adheres to Indonesian government regulations requiring annual employee health check-ups. This study obtained the medical check-up data from workers who completed health check-ups in 2022 and 2023. The examination included the following components: (1) Physical examination: body mass index (BMI), and blood pressure (3) Laboratory tests: These included blood glucose level, creatinine measurement, and estimated glomerular filtration rate (eGFR) calculation. Data was gathered from company's clinic with permission from company management. Workers who underwent medical examinations between 2022 and 2023 and provided signed informed consent were included as study subjects. However, individuals who participated in only one year of health examinations were excluded from the study.

This study used heat exposure measurements conducted in August 2017 and March 2018. An area heat stress monitor (Model QuesTemp°34, Quest Technologies, USA) was used to measure Wet-Bulb Globe Temperature (WBGT) following recommendations from the American Conference of Governmental Industrial Hygienists (ACGIH), USA.[20] The measurements were conducted twice a year, between 9:00 a.m. and 5:00 p.m., with periodic readings taken every 15 minutes throughout the day, using two WBGT instruments operated by two trained personnel. The measurements were taken within a single day to ensure representative data collection while minimizing disruption to operational activities. These repeated measurements were used to determine the average WBGT value at each worksite. The workers were categorized as "high heat-exposed" meant heat stress levels exceeded the Threshold Limit Value (TLV) for safe manual work set at 27.5°C for heavy workloads (e.g., fast walking and carrying loads) and 28°C for moderate workloads (e.g., walking at 3–4 km/h and light lifting).[20] All workers in this study were exposed to light or moderate workloads. Based on these conditions, a temperature of 28°C was chosen as the cutoff for defining heat stress for this study. The workers wore thick cotton uniforms over their casual clothing in this factory. The observation revealed that the factory has limited ventilation.

The primary outcome of interest was the prevalence of Chronic Kidney Disease (CKD), defined by a creatinine level greater than 1.2 mg/dL and an eGFR less than 60 mL/min/1.73 m^2 for two consecutive years.[21] The secondary outcome was the prevalence of reduced kidney functions if they had a creatinine level greater than 1.2 mg/dL for two consecutive years but the eGFR values were 60 mL/min/1.73 m^2 and more. Additional covariates collected included demographic factors (age, sex, duration of work, work division, and employment status), obesity, and comorbid conditions such as diabetes mellitus and hypertension.

The characteristics of study subjects was summarized using descriptive analysis. Scalar variables were presented as means and standard deviations (SDs), while categorical variables were presented as numbers of observations and percentages. Bivariate analysis was performed using Chi-square tests, and multivariate logistic regressions were employed to estimate the odd ratios (OR), and adjusted OR for CKD and reduced kidney function. The independent variable in this study was heat stress, while the dependent variable was chronic kidney disease (CKD) incidence. The potential confounders adjusted are age, diabetes mellitus, hypertension, and obesity. All statistical analyses were conducted using SPSS software, with a two-tailed p-value of 0.05 considered statistically significant.

This study protocol was reviewed and approved by the Institutional Review Board of Binawan University (approval No. 197/KEPK-UBN/X/2023). Informed consent was obtained from all participants at enrollment.

Results

A total of 675 workers were eligible for this study, with an average age of 40.07 and the vast majority being male (99.7%). Among them, 47% were obese, 16.7% had hypertension, and 5.5% had diabetes mellitus. Over 60% of the subjects have been employed in the industry for over five years, and 96.3% were staff members (Table 1).

The heat stress exposure assessment revealed that 34 out of 40 measured locations in dry season and 31 out of 40 measured locations in

Table 1 Subject Characteristics

Variables	Category	Mean (SD)/n	%
Age (years)		40.07 (22–56)	
Gender	Male	673	99.7
	Female	2	0.3
Employment level	Senior Staff	25	3.7
	Staff	650	96.3
Duration of employment	≤5 years	244	36.1
	>5 years	431	63.9
Diabetes mellitus	No	638	94.5
	Yes	37	5.5
Hypertension	No	562	83.3
	Yes	113	16.7
Obesity	No	358	53
	Yes	317	47
Workplace temperature	<28.2 °C	218	32.2
	28.2-30 °C	26	3.8
	>30 °C	432	64

Table 2 Distribution of Reduced Kidney Function and CKD According to Risk Factor

Risk Factor	Reduced Kidney Function			CKD		
	No (n=638) n (%)	Yes (n=37) n (%)	p-value	No (n=669) n (%)	Yes (n=6) n (%)	p-value
Age >40 years						
No	334 (97.0)	10 (3.0)		342 (99.4)	2 (0.6)	
Yes	304 (91.8)	27 (8.2)	0.003	327 (98.8)	4 (1.2)	0.368
Employment level						
Senior Staff	23 (92)	2 (8)		25 (100)	0 (0)	
Staff	615 (94.7)	35 (5.3)	0.573	644 (99)	6 (1)	0.629
Duration of employment						
≤5 years	37 (100)	0 (0.0)		243 (99.6)	1 (0.4)	
>5 years	601 (94.2)	37 (5.8)	0.124	426 (98.8)	5 (1.2)	0.318
Diabetes mellitus						
No	603 (94.5)	35 (5.5)		633 (99.2)	5 (0.8)	
Yes	35 (94.6)	2 (5.4)	0.983	36 (97.3)	1 (2.7)	0.227
Hypertension						
No	542 (96.4)	20 (3.6)		560 (99.6)	2 (0.4)	
Yes	96 (84.9)	17 (5.1)	0.00	109 (96.4)	4 (3.6)	0.001*
Obesity						
No	348 (97.2)	10 (2.8)		358 (100)	0 (0)	
Yes	290 (91.5)	27 (8.5)	0.001	311 (98.1)	6 (1.9)	0.009*
Workplace temperature (°C)						
<28.2	207 (95.4)	10 (4.6)	0.00*	215 (99.1)	2 (0.9)	0.001*
28.2–30	20 (76.9)	6 (23.1)		24 (92.3)	2 (7.7)	
>30	411 (95.1)	21 (4.9)		430 (99.5)	2 (0.5)	

rainy season had heat stress values that exceeded the recommended threshold limit values (TLV). This included control rooms and air-conditioned areas such as offices. The average Wet Bulb Globe Temperature (WBGT) was 29.4±2.4°C, resulting in 96% of workers experiencing WBGT exposures above the TLVs (Figure 1).

Table 2 presents the distribution of risk factors for reduced kidney function and CKD. Reduced kidney function was found in 37 (5.5%) subjects, and CKD was present in 6 (0.9) subjects. Risk factors for reduced kidney function and CKD were workplace temperature, hypertension, and obesity.

Table 3 shows the odds ratio (OR) and adjusted OR (aOR) for reduced kidney function. The OR of exposing workplace temperature 28.2–30 ^{0}C was 6.2 (95% CI: 2.044–18.868) and when adjusted with obesity and hypertension the adjusted OR was 4.504 (CI 95% 1.372–14.792).

Table 4 displays the odds ratio (OR) and adjusted OR (aOR) for CKD. The OR of exposing workplace temperature 28.2–30^{0}C were 8.958 (95% CI: 1.207–66.515). After adjusted for age, obesity, and hypertension, the odds ratio was not statistically significant (Table 4).

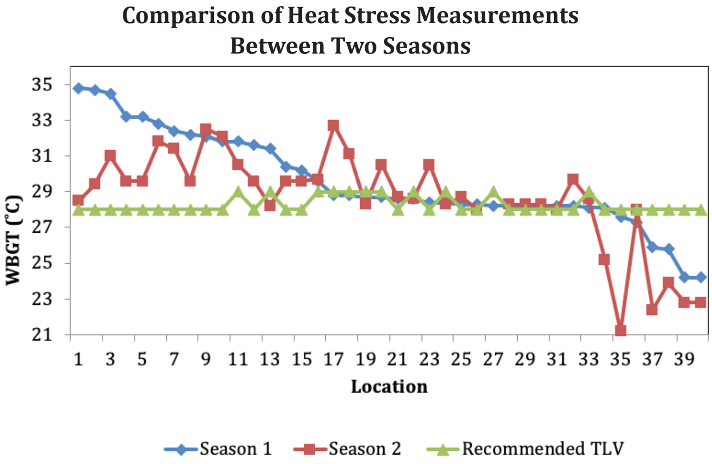

Figure 1 Heat stress (WBGT) Across Two Seasons Compared with the ACGIH Threshold Limit Value (TLV)

Discussion

This study explored the prevalence and risk factors of reduced kidney function and chronic kidney disease (CKD) among factory workers in a heat-exposed industrial setting in Indonesia. It found that the prevalence of reduced kidney function was 5.5%, and the prevalence of CKD was 0.9%. The significant risk factors for reduced kidney function were workplace temperature, hypertension, and obesity. However, when it comes to CKD there is no single significant risk

Table 3 Risk Factors for Reduced Kidney Function

Risk Factor	Reduced Kidney Function No n (%)	Reduced Kidney Function Yes n(%)	OR*	95% CI	AOR*	95% CI
Age >40 years						
No	334 (97.0)	10 (3.0)	1.0		1.0	
Yes	304 (91.8)	27 (8.2)	2.9	1.43–6.23	0.9	0.98–4.61
Hypertension						
No	542 (96.4)	20 (3.6)	1.0		1.0	
Yes	96 (84.9)	17 (5.1)	4.7	2.43–9.49	3.0	1.47–6.41
Obesity						
No	348 (97.2)	10 (2.8)	1.0		1	
Yes	290 (91.5)	27 (8.5)	3.2	1.54–6.81	2.3	1.07–5.13
Workplace temperature (°C)						
<28.2	207 (95.4)	10 (4.6)	10		1.0	
28.2-30	20 (76.9)	6 (23.1)	6.2	2.04–18.87	4.5	1.37–14.79
>30	411 (95.1)	21 (4.9)	1.0	0.49–2.29	1.1	0.52–2.51

OR=odds ratio AOR=adjusted odds ratio CI=confidence interval Confounders: age, hypertension, and obesity *more than one is considered as risk

Table 4 Risk Factors for Chronic Kidney Disease

Risk Factor	CKD		OR*	95% CI	AOR*	95% CI
	No n (%)	Yes n (%)				
Age >40 years						
No	3 42 (51.1)	327 (48.9)	1.0		1.0	
Yes	2 (33.3)	4 (66.7)	2.1	0.38–11.50	0.9	0.14–6.33
Obesity						
No	358 (53.5)	311 (46.5)	1.0		1	0.0
Yes	0 (0)	6 (100)	3116671.5	0.000	17011027.2	0.000
Hypertension						
No	560 (83.7)	109 (16.3)	1.0		1.0	
Yes	2 (33.3)	4 (66.7)	0.1	0.02–0.54	4.5	0.74–27.66
Workplace temperature (°C)						
<28.2	215 (99.1)	2 (0.9)	1.0		1.0	
28.2–30	24 (92.3)	2 (7.7)	8.9	1.21–66.52	6.6	0.74–58.82
>30	430 (99.5)	2 (0.5)	0.5	0.07–3.57	0.5	0.76–4.04

CKD=chronic kidney disease, OR=odds ratio, AOR=adjusted odds ratio CI=Confidence Interval, *more than one is considered as risk, confounders: age, hypertension, and obesity

factor was identified in this study.

The factory environment demonstrated heat exposure levels that exceeded international guidelines, placing workers at risk of heat-related illnesses (HRI).[6,22] The elevated workplace temperatures exposed workers to unsafe WBGT levels at both years. This study found that workplaces lack ventilation and automation, which may make workers more susceptible to severe heat exposure. Workers at danger of heat stress due to intense workloads regardless of workplace temperature.[23]

The prevalence of CKD found in this study was higher than that of the general Indonesian population, namely more than two times the prevalence reported in the general population. These results indicate that workplace exposure plays a role in causing reduced kidney function and CKD that is similar to what was found in Mesoamerican sugarcane, construction, and Thai salt pan labourers workers.[24,25] When compared to the prevalence of CKD in other worker groups in Indonesia, this study shows a lower prevalence. Research on farmers in West Java, Indonesia, showed a high prevalence of CKD among farmers. The overall prevalence of CKD was 24.9%, and CKDu was 18.6%.[15] However, a lower prevalence of kidney diseases (2.2%) was reported by a cohort study among workers exposed toTh heat stress in Thailand.[26] All the studies finding in the indoor industries concludes that high-heat stress combined with a heavy workload and chronic dehydration are high-risk factors for adverse renal health.[10,27]

The high prevalence in previous research could be caused by (1) outdoor research, where exposure to heat stress will be much higher in outdoor workers compared to indoor workers, and (2) CKD parameters in this study are based on the results of measurements for two consecutive years so that they provide better results. Where, according to the definition of CKD, the eGFR parameter must remain at this value for more than three months, (3) in this study, the research location was a company that carried out occupational health measures so that the effect of healthy workers could influence the lower prevalence of CKD in the indoor worker group. This Company compliance in carrying out medical check-up for workers can be a supporting factor in maintaining worker health. Utilizing medical check-up data to detect kidney disorders will be very useful in protecting workers.

This research is also essential in providing information on CKD aetiology in Indonesia that workplace exposure to heat is one of the risk factors to be studied in future. Hustrini's study of patients receiving dialysis and kidney transplants in Indonesia reported that the significant primary kidney disease was diabetic kidney disease (27.2%), followed by glomerulonephritis (13.0%), hypertension (11.5%), and urolithiasis (10.3%), while a high rate of unknown cause (31.1%) was reported. The authors illuminated that the high rate of unknown cause was primarily due to the inability to detect high-risk populations early or the combined effect of environmental and lifestyle exposures associated with the non-traditional CKD etiology (CKD of unknown etiology/CKDu) that the risk factors include heat stress and dehydration.[28]

The company's heat stress data is limited. However, data collected in 2017 may serve as a valid reference for the company's temperature conditions, given that there have been no significant changes in the work process and outdoor temperature since then. Moreover, this does not necessarily imply that there has been no reduced kidney function or CKD within the last five years.

One of the strengths of this research is the use of two consecutive years of laboratory measurements from the same workers, which provides a clearer reflection of permanent kidney function status. Indonesian regulations that mandate medical check-ups for companies could be instrumental in monitoring kidney function among workers exposed to heat stress. Furthermore, estimated GFR with creatinine data collected over two consecutive years can serve as a reference for the early detection of CKD.[29]

This present study highlights the necessity of adopting a holistic approach to CKD prevention. Undertaking all possible risk factors is crucial to protecting workers with reduced kidney function, and minimizing the likelihood of CKD progression.

These results underscore the importance of a comprehensive approach in CKD prevention efforts. Addressing all potential risk factors is pivotal to protecting workers with existing kidney function issues, preventing further deterioration, and reducing the risk of progression to CKD. This study also demonstrates that annual medical check-up for workers is a critical measure for the early detection of kidney function problems. Furthermore, improving occupational health preventive measures is crucial to protect workers from kidney diseases caused by heat stress.

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