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ORIGINAL ARTICLE

INVESTIGATION OF KIDNEY FUNCTION CHANGES IN SEA SALT WORKERS DURING HARVEST SEASON IN THAILAND

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ABSTRACT

Background. Occupational factors have previously been mentioned as contributing to decreased kidney function and the development of chronic kidney disease of unknown cause. Sea salt workers are one of the occupations facing high outdoor temperatures and a highly, intensive workload.

Objective. The purpose of the study was to examine whether the kidney function of sea salt workers at the beginning of the harvest season differs from kidney function at the end of the harvest season and to identify factors that can predict the change of kidney function.

Material and methods. Data were collected from salt workers (n=50) who were between 18–60 years of age without hypertension, diabetes, and kidney disease in Samut Sakhon province, Thailand. Urine specific gravity (USG) was used for hydration status and the estimated glomerular filter rate (eGFR) was used to measure kidney function. The mixed model was used to find differences over the harvest season and prediction of factors.

Results. On average, the eGFR was estimated to decrease by 15.2 ml/min/1.73 m2 over the harvest season. The decline in eGFR of sea salt workers with moderate and heavy workloads were significantly faster than their light workload counterparts after controlling for other covariates. Similarly, dehydration (USG $\geq$ 1.030) significantly accelerated the rate of kidney function loss.

Conclusions. Our study confirmed exposure to heat over the harvest season leads to decreased eGFR in sea salt workers. The rate of change of eGFR could be predicted by workload and hydration status. Workers with dehydration who performed medium to heavy workloads in farms showed faster kidney function decline than those who performed light workload.

Key words: *heat exposure, agricultural work, kidney function change*

INTRODUCTION

Chronic kidney disease (CKD) is a global disease and one of the three causes of death that has increased in the last 20 years [1, 2]. Common causes of CKD are hypertension, diabetes, and obesity, among others [3]. However, CKD of unknown etiology or CKDu has emerged and received considerable attention in many countries particularly in coastal areas [4]. Kidney biopsies in male patients with CKDu were studied, and it was noted that the specimens were not similar to other normal kidney diseases [5]. The causes of CKDu are not yet established, but research has suggested it may relate to occupational factors, such as prolonged heat exposure, heavy workload, and dehydration [6]. Prolonged heat exposure can cause insensible loss of water and electrolytes in the body, which can lead to substantial fluid deficits and vasoconstriction, which are associated with kidney injury. High physical workload with repeated dehydration can contribute to muscle breakdown and rhabdomyolysis, causing hyperuricemia, which may lead to glomerular hypertension and renal tubular injury [7]. Dehydration is related to kidney function, with an increase in fluid intake associates with a lower risk of CKD and slower kidney function decline [8].

Reports of CKDu among outdoor workers, farmers, and agricultural workers have increased in Thailand and other countries (e.g., Egypt, Sri Lanka, Bangladesh, India, Mexico, Guatemala, El Salvador, Nicaragua, and Costa Rica [9, 10, 11]. CKDu is commonly found among those working at sea level, such as sugarcane workers, whereas the rate of CKDu is lower among those working at high altitudes, such as coffee plantations [10, 11]. The highest prevalence rate of CKDu occurred in sugarcane workers [11], while the

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rate is growing for other agricultural workers, such as corn and cotton workers, as well as in industrial settings, such as construction sites and mines [11]. Agricultural workers face high ambient temperatures in the working environment as their tasks are mostly outdoors in direct sunlight. They are more vulnerable to heat stress, often combined with dehydration. The heat load in the human body is influenced by direct exposure to the sun and high physical exertion. To maintain normal body temperature, sweat is released. This can lead to loss of water and electrolytes, such as sodium and chloride, which may cause acute kidney injury or chronic decreased kidney function. Several studies in the sugarcane farming field found relationships between heat exposure, dehydration, and kidney health. A study from El Salvador reported a change in the estimated glomerular filtration rate (eGFR) over the shift day consistent with repeated dehydration from a high workload in a hot and humid environment [12]. A study from Nicaragua found the eGFR decreased by 10 ml/min/1.73 m^2 in nine weeks during harvest season and decreased in eGFR associated with increase in serum creatinine which may be caused by dehydration [13]. Another study in Nicaragua showed the eGFR decreased during the harvest season in various job tasks among sugarcane workers [14].

Thailand is a country located in the tropical zone and numerous people in Thailand are engaged in agriculture. A study of health impacts of climate change on occupational health and productivity found a temperature of 34.6°C in a vegetable field, which is classified as an extreme cause for caution or as a danger for heat-related illness [15]. A temperatures of 30.6 °C was measured in a sugarcane field [16], and the average temperature of a sea salt working area was found to be 33.83 ± 0.95°C with a high of 35.6°C [17]. A study about occupational heat stress and kidney disease in Thailand showed a high prevalence of heat stress in those with lower income and education levels, and heat stress was more common in men [18]. The harvest season in Thailand starts from January to May when the weather is hot and dry. Sea salt workers cannot harvest in other seasons because sea salt production needs sunlight to evaporate the seawater, which is then left to dry naturally. Sea salt workers work outdoors with intense workloads, consecutively putting in 2–10 hours a day for consecutive days. No shade is provided, and their payment depends on how much they work.

To date, only a few studies have investigated heat exposure, dehydration, and kidney health among agricultural workers in Thailand. One study reported that sugarcane workers were at high risk for heat stress and heat-related symptoms and concluded that an extremely hot environment with a high workload was associated with acute health effects [19]. Another study showed that sugarcane workers who did not drink enough and faced heat stress were more likely to have acute kidney injury [20]. A study on sea salt workers found a strong positive correlation between temperature and a hydration biomarker (i.e., urine specific gravity) [17]. To our knowledge, previous studies have not investigated the change of kidney function among sea salt workers in Thailand. Given that sea salt workers are vulnerable to extreme heat exposure that may lead to kidney disease, it is important to investigate whether Thai sea salt workers are facing risks from their work.

The present study aimed to examine the change in kidney function measured by the eGFR among sea salt workers in Thailand from the beginning of the harvest season to the late season. We hypothesized that the eGFR significantly worsened over the period of approximately three months. Additionally, we explored whether demographic characteristics (i.e., age, gender, and BMI), hydration status (measured by the urine specific gravity), and work-related factors (i.e., the amount of workload, working experience, and hours spent working) could explain the individual changes in kidney function.

MATERIAL AND METHODS

Study design, population and heat exposure

This longitudinal study was conducted during the harvest season of a sea salt farm February–May 2020. A two-time measurement was performed after work. The first examination was held at the beginning of the harvest season in February 2020 (Time 1) and then repeated three months later, near the end of the harvest season in May 2020 (Time 2). More information regarding Time 1 can be found in paper *Luangwilai* et al [21]. Data were collected at Samut Sakhon, Thailand where a sea salt learning center has been established. The chairman of the center provided a list of sea salt workers and the protocol of this study was described to the sea salt workers by our research team. Eighty sea salt workers in this area were screened. Men and women aged between 18–60 years who had worked on sea salt farms for at least one year were randomly selected. Thirty participants who reported having hypertension, diabetes, or kidney disease and not willing to participated were excluded, such that there were 50 sea salt workers in Time 1. Seven participants were lost to follow-up, resulting in 43 sea salt workers in Time 2. The workers in this study area were separated into five tasks including farm owners, deliverers, extractors, pilers, and scoopers (Figure 1). Farm owners usually drive a compactor, check the sea level in each pond, and verify the salinity of salt. Extractors are generally both male and female workers who break the salt out of the ground using a wooden

Farm owners Extractors Pilers

Scoopers Deliverers

Figure 1**.** Working tasks of sea salt workers

tool. Pilers drag the salt into a triangular pile. Scoopers help the delivery persons to scoop the salt into the carts. Lastly, workers who serve as deliverers are men who scoop the salt from the pile into the cart and shove the cart to the storeroom. They work as a team and do not switch roles. Concerning the workload [22], deliverers and extractors perform "heavy work" (> 350 kcal/hr.), pilers and scoopers perform "moderate work" (200–350 kcal/hr.), and farm owners perform "light work" (<200 kcal/hr.).

Heat exposure was measured by the researchers using a standardized wet-bulb globe temperature (WBGT) monitor, model ISO 7243 (3M QUEST temp $32^{o}C$), following the guidelines. WBGT data collection on two observation days at each time point, that is, Time 1 and Time 2, started when the workers began to work outdoors on the sea salt farms. The monitor was set up as close to the workers as possible and calibrated before use. Digital data were recorded every hour, and five parameters were measured, namely, dry-bulb temperature, wet-bulb temperature, globe-bulb temperature, WBGT outdoor, and relative humidity.

This study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, Thailand (COA No. 035/2020). All participants provided their informed consent before participation.

Questionnaire and urine collection after work shift

Face-to-face interviews by the researcher team using validated questionnaires were performed after work at the sea salt learning center. At Time1, the questionnaire included questions on personal characteristics, including age, alcohol consumption, and smoking. Exposure factors and work-related factors, including water and other beverage intakes, frequency of urination, work experience on sea salt farms, and hours spent working were asked at Time 1 and Time 2.

After the work shift, each participant provided 20–50 ml. of mid-steam urine in standard polypropylene specimen containers. For the urinalysis, the samples were sent immediately to a certified laboratory and the urine specific gravity (USG) was recorded, which indicates the hydration status. USG $\geq$ 1.030 was marked as dehydration [23].

Kidney function

Blood pressure, pulse rate, and body weight were measured before blood collection at each time point after the sea salt workers finished working. Two, three ml samples of blood was drawn by a medical technician from a Tambon health promoting center to test the levels of serum creatinine (Scr). Blood samples were packed on ice and immediately sent to a certified laboratory. *Jaffe's* kinetic method was used for Scr kidney biomarkers and the eGFR in this study was calculated using the CKD-EPI equation [24].

Data analysis

We used descriptive statistics including frequencies, percentages, averages, and standard deviation. Moreover, we employed a series of *Wilcoxon* signed-rank tests to compare the biomarkers of sea salt workers between the two time points. To test whether the eGFR changed over time, we implemented a random intercept mixed model with the restricted maximum likelihood (REML) and the *Kenward–Roger* correction for a small sample size. The *Time* variable, indicating whether the outcome was collected near the beginning of the harvest season (Time 1, coded as 0) or the end of the harvest season (Time 2, coded as 1), was included as a sole fixed effect predictor. The mixed model was chosen because it allowed individuals to have different levels of kidney function values (beyond the random error). The mixed model also properly handled missing data (assuming the missing data mechanism was *missing at random*). That is, the mixed model could incorporate available information from a case with missing data on Time 2 without removing the whole case (i.e., removing both Time 1 and 2 observations) from the model. Finally, there was an assessment of what predicted patterns of change.

To investigate whether the demographic characteristics, hydration status, and work-related factors could explain interindividual differences in changes in the eGFR, we fitted a random intercept mixed model by regressing the eGFR on time and other fixed-effect predictors (i.e., age, gender, BMI, hydration status, workload, work experience, and hours spent working). The two-way interactions between the

Table 1. Characteristics of sea salt workers at two study time points in a sea salt farm in Thailand

Factors	Study Time Points	
	Beginning of the Harvest Season Mean ± SD, Median, n (%)	End of Harvest Season Mean ± SD, Median, n (%)
Participants (n)	50	43
Gender		
Male	29 (58.0)	24 (55.8)
Female	21 (42.0)	19 (44.2)
Age	47.16 ± 11.28, 51.00	49.51 ± 10.05, 53.00
< 29	6 (12.0)	3 (6.0)
30–39	5 (10.0)	3 (6.0)
40–49	12 (24.0)	(20.0)
≥ 50	27 (54.0)	27 (54.0)
Weight (kg.)	68.64 ± 14.96, 65.50	65.88 ± 13.13, 65.00
Height (cm.)	164.30 ± 9.47, 163.50	162.72 ± 8.19, 163.0
BMI	25.57 ± 5.76, 25.54	25.53 ± 5.70, 24.84
Underweight (< 18.50)	3 (6.0)	3 (7.0)
Normal range (18.50–24.99)	22 (44.0)	20 (46.5)
Overweight (25–29.99)	15 (30.0)	11 (25.6)
Obesity (≥ 30)	10 (20.0)	9 (20.9)
Systolic BP (mm Hg.)	138.54 ± 21.61, 134.0	135.40 ± 15.80133.0
Diastolic BP (mm Hg.)	87.98 ± 15.01, 87.0	83.0 ± 9.16, 82.0
Pulse rate (per minute)	86.92 ± 13.79, 83.50	86.42 ± 13.76, 83.0
Herbal supplement		
Did Not Use	47 (94.0)	40 (93.0)
Uses	3 (6.0)	3 (7.0)
Alcohol drinking status		
Did Not Drink	30 (60.0)	27 (62.8)
Drank	20 (40.0)	16 (37.2)
Smoking status		
Did Not Smoke	34 (68.0)	28 (65.1)
Smoke	16 (32.0)	15 (34.9)
Water intake, ml.	1530 ± 665.55, 1500	1883.72 ± 705.73, 2000
Beverage intake		
Did not drink	15 (30.0)	10 (23.3)
Did drink	35 (70.0)	33 (76.7)
Energy drink	15 (30.0)	10 (23.3)
Electrolyte drink	5 (10.0)	1 (2.3)
Sugary drink	9 (18.0)	7 (16.3)
Coffee	6 (12.0)	5 (11.6)
Combined	-	10 (23.2)
Hours spent working	5.16 ± 2.27, 5.0	5.07 ± 2.32, 4.00

time and each predictor (e.g., *Time x Workload*) were separately added to the mixed model one by one, to see whether the predictor could predict the rate of change in the eGFR. The final model contained statistically significant predictors and lower terms of significant interaction(s). To gauge the robustness of our findings, we also examined several other configurations. All data analyses were conducted using SPSS version 25 for Windows.

RESULTS

Characteristics and work-related factors

Characteristics of sea salt workers at the two study time points are shown in Table 1. There were more male participants than female in the study. The mean age of sea salt workers in Time 1 and Time 2 was 47.16 and 49.51 years, respectively. The participants BMI was in the normal range. Most participants reported they did not use herbal supplements, around half smoked and drank alcohol. The average water intake reported at the beginning of the harvest season was about 1.5 L and increased slightly to 1.8 L in the late harvest season. Besides water, more than 70% of participants drank other beverages (e.g., energy drink). Participants spent about five hours working, on average.

Heat exposure, dehydration and kidney function

The heat exposure measurements using WBGT at two time points are presented in Figure 2. All parameters increased during the late harvest season. On average, the outdoor WBGT was estimated to increase by 4.62°C, from 28.84°C at the beginning of the harvest season to 33.46°C during the late harvest season.

The biomarkers of sea salt workers are presented in Table 2. The mean of the USG was 1.024 at Time 1 and 1.027 at Time 2, with a significantly difference over the season (p-value = 0.015). In this study, the cut point for dehydration was USG ≥ 1.030; 58% of the participants were dehydrated after work at Time1 and 60% were dehydrated at Time 2. Serum creatinine increased substantially from 0.95 mg/dL to 1.098 mg/dL over the season (p-value <0.001). The eGFR decreased significantly from 86.56 ml/min/1.73 m^2 at Time 1 to 71.91 ml/min/1.73 m^2 at Time 2 (p-value < 0.001).

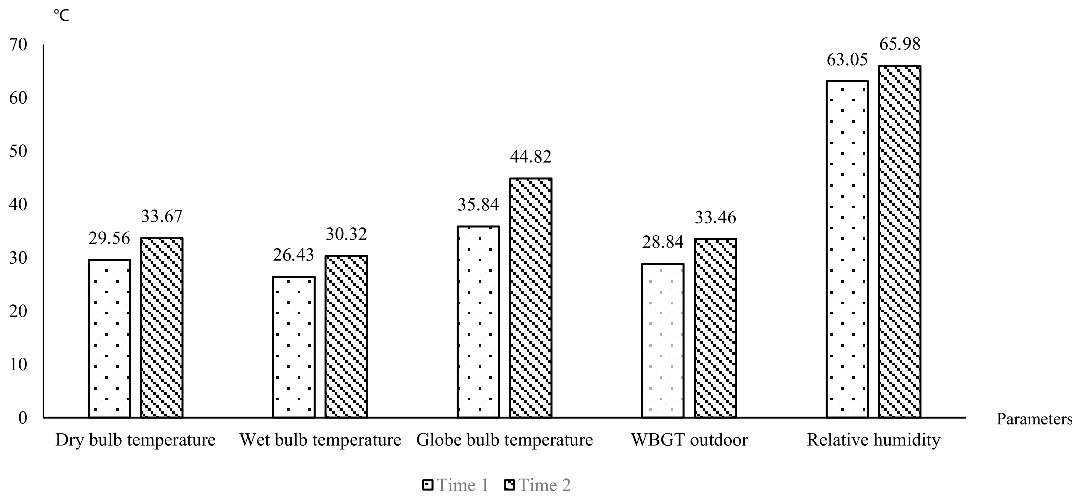

Figure 2. Wet bulb globe measurement between two time measurements

Table 2. Biomarkers in sea salt workers at two study time points in thailand

Study time points	Beginning of the harvest season	End of harvest season	Comparison of two seasons[a] (*P*-value)
	Mean ± SD, Median n (%)	Mean ± SD, Median n (%)	
Participants (n)	50	43	
Urine biomarker			
pH	5.26 ± 0.52, 5.00	5.14±0.35, 5.00	0.153
Urine specific gravity	1.024 ± 0.007, 1.025	1.027 ± 0.006,1.03	0.015*
Serum biomarker			
Serum creatinine (mg/dL)	0.95 ± 0.20, 0.9	1.098 ± 0.22, 1.10	<0.001*
Kidney Function			
eGFR-EPI, ml/min/1.73 m^2	86.56 ± 16.47, 90.60	71.91 ± 16.92, 69.60	<0.001*

Notes. [a] Wilcoxon Signed Rank Test, *Association significant at p-value < 0.05

Kidney function

Change Over Time. The result from the random intercept mixed model with time as a single predictor showed a significant decline in the eGFR from Time 1 to Time 2, b = -15.2, $t(44.135)$ = -5.687 p < .001, 95% CIs [-20.547, -9.796], supporting our hypothesis. Specifically, on average, the eGFR was estimated to decrease by 15.2 ml/min/1.73 m^2, that is, from 86.6 ml/min/1.73 m^2 at the beginning of the harvest season (SD=11 ml/min/1.73 m^2) to 71.4 ml/min/1.73 m^2 at the end of the harvest season.

Predictors of differences in change in the kidney function.

As shown in Table 3, all predictors were included (without interaction effects) to predict the eGFR (Model 1). This model showed that time was strongly predictive of the eGFR after adjusting for other predictors. One interaction at a time was then introduced to the model. Among the two-way interactions, it was found that only *Time x BMI*, *Time x USG*, and *Time x Workload* were significant (Models 2–4). However, only *Time x USG* was significant when including all three interactions in the same model (Model 5). After excluding *Time x BMI*, both *Time x USG* and *Time x Workload* were significant (Model 6). The nonsignificant predictors were further excluded. The final random intercept mixed model (Model 7) included time, age, workload, hydration status, and two interactions (i.e., *Time x USG* and *Time x Workload*). This model suggested that the rate of change in the eGFR could be predicted by workload and hydration status after controlling for other predictors, meaning that the kidney function of sea salt workers with moderate and heavy workloads declined significantly faster than their light workload counterparts with similar characteristics. Similarly, dehydration (USG ≥ 1.030) significantly accelerated the rate of kidney function loss. Additionally, the result showed that older people had significantly lower eGFR compared to their younger peers with similar characteristics.

Additional analyses

It was found that one sea salt worker who was a farm owner had a noticeable increase in eGFR from 75.7 at Time 1 to 136.5 at Time 2 (Figure 3), meaning that the kidney function of the worker greatly improved. Although there was no evidence of any error in the laboratory result or the coding procedure, we examined the robustness of the findings by removing the eGFR value (i.e., 136.5) and the corresponding value of serum creatinine (i.e., 0.5) that was used in the calculation of the eGFR, from the data. The mixed model (using the same predictors as Model 7) indicated that the interaction between time and workload was marginally significant (p=0.098) and the interaction between time and hydration status was significant (p=0.039) after controlling for age. Moreover, when serum creatinine was included as the dependent variable instead of the eGFR, the

Table 3. Results of random intercept mixed models predicting the eGFR

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	b	*b*	*b*	*b*	*b*	*b*	*b*
Intercept	94.05***	95.98**	89.94**	86.96***	85.73***	82.19***	77.84***
Time (baseline)	-13.46***	-20.95	-4.54	-0.68	0.31	9.39	8.54
Gender (male)	-0.59	1.59	1.24	2.11	1.22	1.42	
Age	1.92**	-0.57*	-0.54*	-0.57**	-0.51*	-0.52*	-0.49**
BMI (< 25)	-5.19	-11.14	-5.06	-5.12	-8.77	-5.00	
USG (< 1.030)	-2.71	-1.08	4.92	-1.91	6.41	6.29	7.59
Workload (light)	-5.43	-4.75	-4.03	2.44	2.47	4.34	6.68
Working experience	-0.01	-0.01	-0.05	-0.02	-0.06	-0.06	
Hours spent working	0.59	0.14	0.34	0.79	0.21	0.53	
Time x BMI		13.75*			8.68		
Time x USG			-16.00*		-15.41*	-16.87**	-17.05**
Time x Workload				-16.00*	-12.48	-16.94*	-16.28*
Residual Variance	171.56***	145.62***	155.23***	151.34***	125.09***	131.21**	128.03***
Intercept Variance	87.82	107.27*	93.66*	103.84*	117.55*	113.22*	109.64*

Notes. Total N = 93 (N = 50 from Time 1 and N = 43 from Time 2). Age, working experience, and hours spent working were centered at their means (i.e., 47 years old, 16 years, and 5 hours, respectively). A group in brackets refer to the reference group (coded as 0). *p < .05, **p < .01, ***p < .001.

interactions between time and workload (p=0.049) and time and hydration status (p =0.039) remained statistically significant after controlling for age. We concluded that the findings from additional analyses were consistent with the original results, showing that the kidney function of sea salt workers with a light workload or without a sign of dehydration tended to decline at a slower rate.

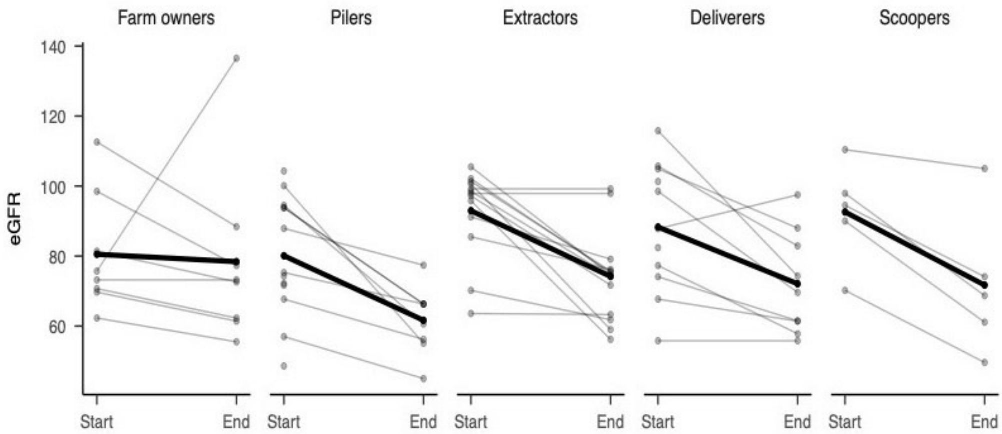

Figure 3. Change of eGFR for all 50 participants grouped by position. Black lines represent the averages of the eGFR across participants

DISCUSSION

Sea salt workers who faced heat exposure over the harvest season can have changes in kidney function. This study aimed to examine the changes in kidney function and investigate factors that explained these individual changes in kidney function from the beginning of the harvest season to close to the end of the harvest season. We found that sea salt workers in Thailand were at the risk of rapid kidney function decline. On average, the eGFR decreased by 15.2 ml/min/1.73 m^2 in three months, which was higher than our expected outcome and higher than found in previous studies. For example, a study from Nicaragua on 51 cane cutters found the average eGFR decreased by 3 ml/min/1.73m^2 over five months [25] and another study in the same country found that the mean eGFR of 29 sugarcane workers decreased by 10 ml/min/1.73m^2 in nine weeks [13]. We were not aware of any relevant studies that found the reduction in eGFR over 10 ml/min/1.73m^2 in three months. This may be because of the characteristics of job tasking of sea salt workers, which include human labor and high-intensity work in combination with the working environment factors such as heat exposure, open land fields, lack of shade, and the sunlight needed for sea salt production which contrasts with heat prevention guidelines [26]. Another reason maybe because age is associated with kidney function. More than half of our participants were older than 50 years. Yet, our participants still had lower average eGFR compared to sugarcane cutters in Thailand with similar age range [20]. Some studies revealed that NSAIDs and herbal supplement were associated with a decrease in eGFR [6], but this study showed only approximately 6% of sea salt workers took paracetamol for pain release and 7% took herbal supplement. Future investigations through follow-up or cohort studies will provide clearer information as this study was conducted only over a harvest season in a salt farm.

The rate of change in the eGFR could be predicted by workload and hydration status. Workers with dehydration who performed moderated and heavy workload showed a faster kidney decline. Working as a sea salt worker required strenuous labor in a hot and humid environment. Sea salt workers perform outdoor work for about two to 10 hours a day, depending on how many salt ponds are ready to be harvested, with an average of about five hours spent working. The sea salt harvest season period is between January to May every year. Our assessment of heat exposure showed that the average WBGT was estimated to increase by 4.62°C, from 28.84°C at the beginning of the harvest season to 33.46°C at the end of the harvest season. At the beginning of the harvest season, all sea salt workers did not work in extreme conditions according to the Thailand regulations in place for working in hot conditions. However, workers with moderate and heavy workloads worked in conditions that were too hot in the late harvest season (workers with light, moderate, and heavy workloads should not work in temperatures over 34°C, 32°C, and 30°C, respectively) [27]. Recent literature among 25 male paddy farmers stated that when engaging in physical work or high-intensity manual work, uric acid increased after muscle breakdown, following which kidney injury could happen through hyperuricemia [28].

It was hypothesized that working in hot and humid conditions could lead to dehydration. A study conducted in the summer in Japan reported 42% of construction workers were dehydrated after work [29]. In our study, we found that dehydration could predict kidney decline. We examined the USG for hydration status. USG significantly increased over the season (Table 2) and 58% of participants were dehydrated after work at the beginning of the harvest season while up to 60% were dehydrated at the end of the harvest season. This is about 10% higher than what was found in a recent study among sugarcane workers in Thailand [16]. Sea salt workers engage in intense manual labor in direct sunlight. Workers in high heat can increase their core temperature, then observe an increase in evaporation through the skin to cool down their body. In that state, water loss from evaporation and inadequate water intake can cause dehydration. American conference of government industrial hygienist (ACGIH) recommended consuming about 235 ml. of water every 20 min during work in hot conditions [29, 30]. Sea salt workers reported a mean water intake of about 1.5 L at the beginning of the harvest season and 1.8 L during late harvest season, which was lower than the recommendation. This may be because of longer distances to toilets and payments which affect the entire team. This encourages them to drink less water and take less rest periods similar to a previous study among 97 crop workers [31]. Studied in sugarcane workers in hot environments with low water intake had inferior kidney biomarkers compared to those who drank enough water [20]. Sugarcane cutters from El Salvador reported temperatures of 34–36°C in the workday, whereas their water intake was 0.8 L per hour. The mean USG increased after work, and eGFR was reduced in 14% of workers. This study concluded that dehydration from high workloads in hot environments is an important factor for kidney function decline [32]. Field workers were at greater risk of kidney function decline over the harvest season compared to non-field workers, which is associated with reduced kidney function [33]. Physical work with heat exposure and dehydration is a common predictor for kidney function decline [34]. Previous studies among paddy farm workers also mentioned that the pathophysiological pathway of dehydration could lead to kidney function decline. Prolonged heat stress exposure in physical jobs with repeated dehydration can cause acute kidney injury, developing into CKDu [28].

This study has several limitations. One major limitation is that only one research area was selected, so that the sample size was small. Second, heat measurement was assessed by WBGT for only two days at each time point. Furthermore, heat exposure can be assessed by standard tools, but it would be more beneficial to measure individual body core temperatures in future studies. Third, data was collected from only two time points in this study, which is a limited statistical technique. Lastly, most of participants in this study were over 50 years. Our results cannot be generalized to younger populations. Prospective studies should collect data for more than two times points with continuous monitoring environment exposure and biomarkers. Investigation about causal factors which could be associated with kidney function declined among high heat exposure workers in Thailand are the need for more research.

CONCLUSIONS

This study found that exposure to heat over the harvest season in sea salt workers leads to decreased eGFR. The rate of change of eGFR could be predicted by the workload and hydration status. Workers with dehydration who performed as deliverers, extractors, pilers, and scoopers at the sea salt farms showed a faster kidney function decline than those who had a light workload. Training or education programs about preventing heat illness at the individual or community levels may be beneficial for sea salt workers in Thailand.

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Conflict of interest

The authors declare no conflict of interest.

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