EVALUATION OF OCCUPATIONAL INDOOR HEAT STRESS IMPACT ON HEALTH AND KIDNEY FUNCTIONS AMONG KITCHEN WORKERS

By

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Abstract

Introduction: Occupational heat exposure is a major occupational health issue and a great number of indoor workers may be at risk of heat stress and its consequences, particularly those working near a radiant heat source as in kitchens. **Aim of Work:** To assess heat stress in hospital kitchen environment through environmental heat measurements using the wet-bulb globe temperature index , to evaluate the prevalence of heat related illness and to detect the impact of chronic indoor occupational heat exposure on the kidney health and functions through measurement of urinary interleukin-18 and neutrophil gelatinase-associated Lipocalin. **Materials and Methods:** A cross sectional comparative study was conducted upon 87 workers in a large scale hospital kitchen at Cairo, Egypt. The workers were classified into two groups: the directly heat exposed group (40 cookers) who were directly in contact with thermal radiation. The second group was the indirect heat exposed group (47 workers) who were involved in activities away from heat contact. Both groups were subjected to a detailed questionnaire including history of self-reported heat related heat illnesses, clinical examination, measurement of urinary levels of interleukin-18 and neutrophil gelatinase-associated Lipocalin. Environmental heat measurements at different workplaces were assessed. **Results:** In the cooking areas, the mean value of wet-bulb globe temperature was (32.4±1.4) that exceeded the threshold limit value (TLV) recommended by American Conference of Government Industrial Hygienists (28°C). The median and interquartile range of urinary biomarkers were significantly higher among the directly heat exposed group (32.4, 22.7-51.9 and 102.6, 77.9-161.5) for interleukin-18 (IL-18) and neutrophil gelatinase-associated Lipocalin (NGAL) respectively. There was a statistically significant fewer water cups drunken by the direct heat exposed workers (p value <0.001). The direct heat exposed group reported highly significant occupational heat related symptoms as heat cramps, excessive sweating, headache, dizziness, fatigue/ tiredness and excessive thirst ($p < 0.001$). **Conclusion:** The current study revealed that kitchen workers particularly cookers were chronically exposed to excessive indoor heat stress exceeding the permissible limit producing heat related illness and subclinical kidney affection.

Key words: Heat stress, Indoor heat, Wet-bulb globe temperature (WBGT), Interleukin-18 (IL-18) and Neutrophil gelatinase-associated Lipocalin (NGAL).

Introduction

Occupational heat exposure in different workplaces including kitchens is a physical hazard and a major occupational health and safety issue that can cause great impact on workers' health and productivity (Kjellstrom et al., 2009 and Singh et al., 2016).

Lots of indoor workers may be at risk of heat stress and its consequences, particularly those working near a radiant heat source, such as ovens, furnaces and boilers as in kitchens and other workplaces. These workers are exposed to high temperatures, strong physical activity, and inadequate work practices that do not allow for sufficient rehydration breaks (Nerbass et al., 2017). Heat stress is the metabolic heat produced by the body in addition to the environmental heat obtained from the surrounding environment minus the heat dissipated from the body to the environment. When heat loss through sweat evaporation is insufficient, and other physiological responses can't prevent elevation of core temperature, heat related illness (HRI) develop (Jacklitsch et al., 2016). Such a stressful condition often happens in conjunction with dehydration and volume depletion and manifests with a wide range of heat-related symptoms such as, headache, muscle cramps, rashes, fatigue, dizziness and syncope (Crowe et al., 2015).

The mechanism of kidney dysfunction due to heat stress (heat nephropathy) may be related to repeated heat stress and accompanied dehydration that lead to hyperosmolarity, subsequent activation of vasopressin, increased urinary concentration and renal vasoconstriction (Roncal-Jimenez et al., 2015). Repeated heat stress and dehydration can result in repeated subclinical ischemic kidney injury that may progress to chronic kidney disease (Weiner et al., 2013). Also physical exertion in hot environment results in redistribution of blood supply to muscles and skin on the expense of kidney leading to acute kidney injury (AKI) and impairment of kidney functions (Pryor et al., 2020).

Neutrophil gelatinase-associated lipocalin (NGAL) is a protein belonging to the lipocalin superfamily and it is a very sensitive and early marker of kidney injury, it is released in the urine as a result of distal tubular injury (Charlton et al., 2014). Interleukin -18 is a pro-inflammatory cytokine, produced by immune cells as monocytes and macrophages and it is excreted in the urine following ischemic proximal tubular injury (Liu et al., 2013). Both biomarkers were considered as promising useful tools for prediction of subclinical kidney injuries among heat exposed workers in several studies (Laws et al., 2016 and Chapman et al., 2020).

Aim of Work

The aim of this study is to assess heat stress in hospital kitchen environment through environmental heat measurements at different kitchen workplaces using the wet-bulb globe temperature index (WBGT), to evaluate the prevalence of heat related illness (HRI) due to indoor heat exposure and to detect the impact of chronic indoor occupational heat exposure on the kidney health and functions through measurement of urinary interleukin-18(IL18) and neutrophil gelatinase-associated Lipocalin (NGAL) biomarkers .

Materials and Methods

Study design: It is a cross-sectional comparative study.

Place and duration of the study: The study was done in a large scale hospital kitchen at a big tertiary hospital at Cairo, Egypt from April to May 2021.

Study sample: The study was conducted on 87 kitchen workers who are exposed to indoor heat from a total number of 132 workers. They were all workers who fulfill the inclusion criteria and accepted to participate in the study.

Inclusion and exclusion criteria: All eligible workers were invited to participate in the study. Eligibility criteria included those with regular employment in the kitchen for at least one year, with the exclusion of those who taking nephrotoxic medications and workers with chronic diseases like hypertension, cardiovascular diseases and diabetes and those who refused to participate in the study.

The study population was classified into two groups; the first one was the directly heat exposed group: it included (40) cookers who were directly in contact with thermal radiation source as ovens, cookers, furnaces and stoves. The second group was the indirect heat exposed group: (47) workers who were involved in activities away from heat contact like those responsible for food preparation, dish washing, storage, cleaning and waste removal.

Study methods: Both groups were interviewed and subjected to the following:

I-Questionnaire: A written Arabic interview questionnaire developed by the researchers including: sociodemographic history (age, gender, marital status, smoking habits), occupational history (duration of employment, and working hours, working site, presence of periodic rest break, previous job and description of all work activities at the kitchen), in addition to history of occupational risk factors at the work environment such as (overcrowdings, ventilation source, type and character of clothes and the use of personal protective equipment (PPE)). Present and past history of any preexisting health problems was also taken. Self-reported symptoms of heat related illnesses (HRI) were reported.

A workers' health was considered as affected by heat stress if they experienced one of the following heat related symptoms at work i.e., heat cramps, heat rash, sweaty hands, headache, fainting, fatigue/exhaustion, excessive sweating or excessive thirst (Venugopal et al., 2016).

II-General and local examination

III-Laboratory investigations

A urine sample was taken, centrifuged, and the supernatant was used for biochemical measurements. Interleukin 18 (IL-18) and Neutrophil gelatinase-associated Lipocalin (NGAL) were measured in human urine using commercial ELISA kits manufactured by Bioassay Technology Laboratory, China. In order to normalize the levels of both urinary IL-18 and NGAL, urine creatinine was measured by using Jaffe's colorimetric method (Alkaline Picrate) (Tietz, 1995) using commercial kits manufactured by Biosystems, Spain.

IV- Environmental heat measurements: Fourteen measurements were performed at different work sites at the kitchen upon several visits throughout their working hours. A preliminary visit was performed before environmental heat monitoring to assess the work environmental condition and allocate the sites of direct and indirect heat exposure.

At the cooking area where there was a direct contact to heat generated from stoves, steamers and ovens, 5 readings were taken. Other areas where no direct close contact to heat source such as, food preparation area, washing area and storage area, 3 readings were taken for each of them.

The Wet-Bulb Globe Temperature (WBGT) was recommended as a measurement tool for determining heat stress imposed on an individual (ACGIH, 2017). The QUEST Temp 32°C (Quest Technologies, a 3M Company, USA) is a monitoring instrument that measure 3 parameters: dry temperature (DB), natural wet bulb temperature (NWB) and globe temperatures (GT). WBGT is a weighted average of three temperature sensors using the following formula: WBGT (indoors): = 0.7 NWB + 0.3 GT. The QuesTemp32°C was placed at a height of 3.5 feet (1.1m) for standing individuals and 2 feet (0.6 m) for seated individuals.

The workload was considered as moderate work category with work-rest cycle 75-100%. All workers were acclimatized, as they work regularly at the kitchen and they not recently returned from an absence of >1 week. Workers wear cotton shirts and pants, for that after adding clothing adjusted factor (CAF), there was no effect of clothes on WBGT. All these data were collected on-site, to make appropriate adjustments to the measured WBGT value (ACGIH, 2017).

Consent

An informed consent was taken from all participants after explaining the objectives of the study and confidentiality was maintained.

Ethical approval

The present study was done in compliance with declaration of Helsinki and an approval from Ethical Committee of Occupational and Environmental Medicine department at Cairo University was obtained.

Data Management

After data collection, data entry then analysis by using SPSS program (version 16) was done. Comparing between groups was done by using

Pearson Chi square- test for qualitative data, and for quantitative data Mann-Whitney and independent t tests. Also spearman's correlation was done to assess the association between quantitative variables. The level of significance was taken at 0.05. So, $p \leq 0.05$ was considered to be significant.

Results

Table (1): Socio-demographic and occupational characteristics of the studied workers.

Heat exposure status / Socio-demographic characteristics	Directly heat exposed group No = 40		Indirectly heat exposed group No = 47		Significance test p value
	No	%	No	%	
Age /years Mean ±SD	45.1± 9.1		46.02± 7.4		t=0.5 p =0.1
Sex -Male -Female	 25 15	 62.5 37.5	 37 10	 78.7 21.3	x^2 =2.8 p =0.1
Marital status -Married -Unmarried	 35 5	 87.5 12.5	 44 3	 93.6 6.4	x^2 =1 p =0.3
Smoking habits -Yes -NO	 8 32	 20.0 80.0	 16 31	 34.0 66.0	x^2 =2.1 p =0.1
Working duration /years Mean ±SD	17.4±8.4		15.9±8.7		t=0.4 p =0.7
Working hours/day Mean ±SD	6.9±1.1		7.04±1.2		t=0.4 p =0.7
Presence of additional work -Yes -NO	5 35	12.5 87.5	10 37	21.3 78.7	x^2 =1.2 p =0.3

Table (1) showed the socio- demographic and occupational characteristics of the studied workers-(87). No significant differences were observed between both of direct heat exposed and indirect exposed groups as regards age, gender, marital status and smoking habit, smoking index, working duration, working hours/ day and presence of additional work ($p > 0.05$).

Table (2): Environmental heat temperature measurements using the wet bulb globe temperature index (WBGT) at different kitchen work sites.

Work sites	Wet bub temp °C (WB)			Dry bulb temp °C (DB)			Globe temp°C (GB)			Wet bulb globe temperature °C (WBGT)		
	Min	Max	Mean± SD	Min	Max	Mean± SD	Min	Max	Mean± SD	Min	Max	Mean ± SD
Washing area	21.0	23.8	22.5±1.4	26.3	29.4	28.1±1.6	25.5	32.1	29.4±3.5	22.7	25.9	24.4±1.6
Food preparation	23.7	26.7	25.2±1.5	25.9	33.0	29.6±3.6	27.1	32.8	30.7±3.1	24.7	**28.4**	26.9±1.9
Storage area	23.7	26.6	25.2±1.5	25.9	35.3	31.4±4.9	27.1	40.6	34.3±6.8	24.7	**29.8**	27.9±2.7
Cooking area	27.9	32.0	29.6±1.8	31.1	36.7	33.7±2.1	38.0	39.6	38.8±0.7	**30.9**	**34.3**	**32.4±1.4**

Min: minimum Max: Maximum

Table (2) showed that WBGT measurement ranged from the 22.7°C at the washing area to 34.4°C at the cooking area. All measurements were below the recommended TLV (28°C) at the washing area. The maximum reading at the food preparation and storage areas (28.4 and 29.8) respectively were higher than the recommended, while all measurements at cooking area were higher than the recommended TLV with mean of (32.4±1.4).

Table (3): Median and interquartile range of Urinary Interleukin- 18 and Neutrophil gelatinase -associated Lipocalin biomarkers among the studied workers .

Heat exposure status / Markers	Directly heat exposed group No = 40		Indirectly heat exposed group No = 47		Significance test p value
	No	%	No	%	
Interleukin- 18 (IL-18) Median Inter-quartile range (25-75)	32.4 22.7-51.9		9.2 6.4-11.6		Mann-Whitney =8 **p = <0.001 ***
Neutrophil gelatinase -associated Lipocalin (NGAL) Median Inter-quartile range (25-75)	102.6 77.9-161.5		32.4 22.3-41.2		Mann-Whitney =2 **p = <0.001 ***

*: Statistically significant

Table (3) showed that the median and interquartile range of urinary biomarkers IL-18 and NGAL were significantly higher among the directly exposed group compared to the indirect exposed one (p value <0.001).

Table (4): Occupational risk factors among the studied workers.

Heat exposure status / Occupational risk factors	Directly heat exposed group No = 40		Indirectly heat exposed group No = 47		Significance test p value
	No	%	No	%	
Use of personal protective equipment (PPE)					
-Yes	33	82.5	39	83.0	x^2 =0.003
-NO	7	17.5	8	17.0	p =0.9
Number of water cups/ working hours (Mean ±SD)	1.4±0.7		3.9±1.2		t=12.6 **p = <0.001 ***
Presence of periodic break					
-Yes	13	32.5	17	36.2	x^2 =0.1
-NO	27	67.5	30	63.8	p =0.7
Presence of overcrowdings					
-Yes	27	67.5	27	57.4	x^2 =0.9
-NO	13	32.5	20	42.6	p =0.3
Enough ventilation					
-Yes	3	7.5	5	10.6	x^2 =0. 3
-NO	37	92.5	42	89.4	p =0.6

*: Statistically significant x^2 :Chi-Square test

Table (4) showed the occupational risk factors present at the kitchen environment, the majority of workers were committed to the use of PPE in 82.5% among direct exposed and 83% in indirect group. Most of kitchen workers didn't take periodic break in (67.5% and 63.8%) of direct and indirect groups respectively. Overcrowdings were prevalent among both direct and indirect groups (67.5 and 57.4%) respectively. The majority complained of lack of ventilation in (92.5 and 89.4%) among direct and indirect groups respectively. All of these factors showed no statistically significant differences between direct and indirect exposed groups (p > 0.05). As regards number of water cups drunken during working hours, the direct exposed workers had significantly lower number of cups than indirect exposed group (p value <0.001)

Table (5): Self-reported heat related symptoms among the studied workers.

Heat exposure status / Heat related symptoms	Directly exposed No = 40		Indirectly exposed No = 47		Significance test (x^2) p value
	No	%	No	%	
Heat cramps					
-Yes	28	70.0	6	12.8	29.7
-NO	12	30.0	41	87.2	**p = <0.001***
Heat rash					
-Yes	5	12.5	4	8.	0.4
-NO	35	87.5	43	91.5	p =0.5
Excessive sweating					
-Yes	34	85.0	4	8.5	51.4
-NO	6	15.0	43	91.5	**p = <0.001***
Headache					
-Yes	33	82.5	10	21.3	32.4
-NO	7	17.5	37	78.7	**p = <0.001***
Dizziness					
-Yes	9	22.5	3	6.4	4.7
-NO	31	77.5	44	93.6	**p =0.03***
Fainting /Syncope					
-Yes	1	2.5	4	8.5	1.4
-NO	39	97.5	43	91.5	p =0.2
Fatigue/ Tiredness					
-Yes	33	82.5	7	14.9	39.8
-NO	7	17.5	40	85.1	**p = <0.001***
Excessive thirst					
-Yes	29	72.5	8	17.0	27.2
-NO	11	27.5	39	83.0	**p = <0.001***
Lack of concentration					
-Yes	8	20.0	8	17.0	0.1
-NO	32	80.0	39	83.0	p =0.7

* Statistically significant x^2 : Chi-Square test

Table 5 reflects the kitchen workers' perceptions of heat related symptoms. It showed that direct heat exposed group reported highly significant occupational heat related symptoms regarding heat cramps, excessive sweating, headache, dizziness, fatigue/ tiredness and excessive thirst ($p < 0.001$), while there was no statistically significant difference between the two groups as regards heat rash, fainting/syncope and lack of concentration ($p>0.05$).

Discussion

Exposure to high temperature and humidity at the kitchen can represent a risk to the health and safety of kitchen workers and may contribute to heat stress. Kitchen work is a physically demanding job. Workers may lift boxes, pots and crates of food, pushing or pulling trolleys, handing containers, unloading food and drink deliveries, storage for items on shelves that may contribute to high internal metabolic heat production in addition to the environmental heat generated from radiant heat source.

In the present study, heat stress was assessed by measuring of wet-bulb globe temperature index (WBGT). The threshold limit value (TLV) for comparison was used for comparing instead of the action limit because all included workers were acclimatized.

At the cooking areas, the WBGT measurements ranged from (30.9°C - 34.3°C) with mean value of (32.41.4±). The maximum WBGT recorded was at the cooking areas of kitchens (Table 2). These measurements were exceeding the (TLV) recommended by American Conference of Government Industrial Hygienists (28°C) (ACGIH, 2017), because the cookers were in direct contact to radiant heat generated from the surrounding hot objects like furnaces, ovens, stoves and steamers. At the food preparation and storage areas, the maximum readings were exceeding the recommended TLV (28.4 and 29.8) (Table 2); that may be explained by the effect of ill ventilation which augments the effect of hot environment at the kitchen. The previous results proved that kitchen workers and particularly cookers are suffering from occupational heat stress due to indoor heat exposure at their work. These were in accordance with the findings of Ierardi and Pavilonis (2020) who assessed the heat stress among workers of 10 school kitchens in New York, and they found that the indoor WBGT was exceeding the action limits for moderate work in 60% of kitchens and only 30% exceeding TLV for heavy work only.

The current results of indoor WBGT mean value (32.4±1.4) were near to that detected by Rabeiy (2019) at 20 bakeries in Assuit city, Egypt (31.6± 5.0) who evaluated the effect of heat stress upon bakeries workers and he found similarly that WBGT measurements were exceeding TLV for moderate work (28°C).

Similarly, Logeswari and Mrunalini

(2017) detected that WBGT was slightly higher than permissible limits of ACGIH at the cooking area among large kitchen worker in Hostel.On the other hand, Matsuzuki et al (2011) reported that WBGT in front of cookers in hospitals and school kitchens were below the permissible exposure limit even in midsummer days and they explained their result by the presence of adequately controlled environment, but they stated also that the study included only 16 workers from 8 institutions which necessitate further researches.

The median and interquartile range of urinary IL-18 and NGAL were significantly higher among the directly heat exposed group (32.4, 22.7-51.9) for IL-18 and (102.6, 77.9-161.5) for NGAL compared to the indirect exposed group (9.2, 6.4-11.6) and (32.4, 22.3-41.2) for IL-18 and NGAL respectively (p-value <0.001) (Table 3).

Pryor et al. (2020) reported that occupational heat exposure and work exertion were found to produce transient impairment of kidney function which is potentiated if associated with dehydration, as blood will be redistributed to muscles and skin with impairment of renal blood flow. These were in agreement with the findings of Laws et al. (2016) who studied the effect of occupational heat exposure among sugarcane workers in northwestern Nicaragua and they found that field workers were at risk of heat stress and they had increase in urinary NGAL and IL-18 levels especially during harvest season.

Also Chapman et al., 2020 studied the effect of attenuation of hyperthermia and dehydration on the decline of acute kidney injury (AKI) biomarkers upon healthy subjects in Baffalo University , New York , USA. They reported significant increase in NGAL and other biomarkers of AKI among control group who didn’t receive water or cooling in comparison to other groups suggesting the presence of proximal tubular injury.

Also, Shi et al. (2012) investigated the value of serum IL-18 level, as a sensitive biomarker for proximal tubule injury, for assessing the disease progression in chronic kidney disease patients and they detected that those patients with elevated IL-18 had a significant poor renal outcome.

As regards the occupational risk factors present at the kitchen environment which may affect the level of individual tolerance to heat stress; the majority of the studied workers were committed to the use of personal protective equipment (PPE) among both direct and indirect exposed group. Participants in both groups reported presence of inadequate periodic rest break, overcrowdings and inadequate ventilation, all these factors are considered as risk factors of heat stress and showed no statistically significant differences between both groups ($p > 0.05$) (Table 4). The non-significance may be due to working of both groups in the same environment and under the same circumstances.

The kitchen workers of both groups wear gloves, slip resistant footwear, hair cover for cookers and a uniform consisted of cotton pants and shirts upon their clothes. In hot and humid workplaces, light comfortable clothing of natural fibers as cotton allows maximum skin exposure and efficient body cooling by sweat evaporation and thermal comfort (New et al., 2020).

Lack of ventilation will lead to poor air quality and increasing humidity which will aggravate the effect of heat production and excess heat stress. Both groups of kitchen workers reported lack of both natural and artificial ventilation and they reported presence of insufficient windows, fans and fume extractors, also the kitchen was not air conditioned. In addition to overcrowdings and high worker density and lack periodic rest break at cool area was reported by the majority of both groups of kitchen workers (Table 4).

Similarly to the study results, Ierardi and Pavilonis (2020) informed about work risk factors at a New York City school kitchen that may contribute to heat related illness and they mentioned close contact to a radiant heat source from ovens and heating equipment, inadequate ventilation, high worker density and improper work/rest schedule.

The direct heat exposed workers (cookers) drank fewer water cups than indirect exposed group (p value <0.001) (Table 4). This result indicated that cookers were suffering from dehydration which may increase impact of heat stress. This significant difference may be explained by excessive work practice performed by cookers at large hospital kitchen that don’t allow for sufficient rehydration time. In addition, working in the heat, causes sweat output exceeds water intake, resulting in a body water deficit and electrolyte losses. Piil et al. (2018) evaluated the prevalence of dehydration in occupational hot settings and its effects on motor performance; their study revealed that 70% of all workers suffered from dehydration.

So adequate hydration by drinking 5 liters of cold water/day during hot work can improve the cooling of the body and prevents dehydration (Logeswari and Mrunalini ,2017).

The workers' self-reported heat related symptoms were significantly prevalent among direct heat exposed group regarding heat cramps, excessive sweating, headache, dizziness, fatigue/ tiredness and excessive thirst ($p < 0.001$) (Table 5).

Heat related illnesses may develop when the environmental and metabolic heat loads exceed the ability of the body for heat dissipation to the surrounding environment (Tanaka, 2007).

Sweating is a way of heat dissipation of metabolic heat in order to maintain thermal homeostasis. High prevalence of excessive sweating at work among direct exposed group (85%) compared to only (8.5%) among indirect group (Table 5) indicates that there is a stress on thermoregulatory system leading to heat related health problems among the direct heat contact workers (OSHA, 2012).

Cookers reported significantly higher prevalence of heat cramps (70%) compared to indirect group (12.8%) (Table 5); which may be a reflection of water and electrolyte disturbance that results from excessive loss of water and sodium in sweat without adequate replacement (Awahl et al., 2000).These were in agreement with the findings from organized and unorganized Indian work sectors conducted by Venugopal et al. (2016) to profile occupational heat stress impacts on the health and productivity. It showed that workers with heavy workloads reported more heat-related health problem as excessive sweating or thirst, tiredness, cramps, headache, fainting, heat rash or urinogenital issues by 96% ($p < 0.001$).

The current results were in accordance to the findings of Hansen et al. (2018) who studied the impact of heat exposure and hot working conditions among public and workers at Australia and they reported variant heat related symptoms like, headaches, discomfort, muscle fatigue, tiredness / exhaustion and fainting.

Conclusion and Recommendations:

Kitchen workers particularly cookers were chronically exposed to excessive indoor heat stress. Chronic heat exposure and accompanied dehydration resulted in heat related illness and subclinical kidney affection with elevation of urinary NGAL and IL-18 biomarkers. So health education of heat exposed workers is recommended to recognize signs of heat related illness and prevention though adequate regular hydration, periodic rest breaks. Applying adequate ventilation and cooling of workplace and other feasible engineering and administrative controls is a must. In addition to environmental heat monitoring to ensure the effectiveness of control measures and adherence to regulated exposure limits. Periodic medical screening of heat exposed workers and measurement of IL-18 and NGAL biomarkers of kidney to allow for early detection and slow down the disease progression.

Conflict of Interest

There is no conflict of interest.

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