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A review of occupational exposure to heat stress, its health effects and controls among construction industry workers, A case of Jeddah, KSA

Tarek Abokhashabah[1], Bassem Jamoussi[1], Ahmed Saleh Summan[1], Ezz Abdelfattah[2], Ijaz Ahmad[3*]

[1]*Department of Environmental Science, Faculty of Meteorology, Environment and Arid Land Agriculture, King-Abdulaziz University, 21589 Jeddah, Saudi Arabia*

[2]*Department of Statistics, Faculty of Sciences, King-Abdulaziz University, 21589 Jeddah, Saudi Arabia*

[3]*Department of Environmental Science, Faculty of Basic and Applied Sciences, International Islamic University, 44000 Islamabad, Pakistan*

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Abstract

Construction workers face various health hazards, risks, and injuries while working outdoor at construction sites, this will also significantly impact their physical, mental health and productivity. Thermal stress is among the main hazards affecting heavily construction workers. With climatic conditions of most of the cities in the world, there has been a general increase in average temperature which would expose the workers to extreme heat especially in summer. Construction workers who are affected by this high temperature are at elevated risk of heat stress, which may lead to an increased heartbeat and blood pressure, stress and fatigue, heatstroke, and chronic heart disorders. This article aims to review the characteristics and health effects of heat exposure among construction industry workers and to summarize findings from published studies, and ultimately recommending control measures for workplace heat exposure reduction, adaptations, and further research options. Globally, the literature on the effects of scorching heat on the health of outdoor workers has received limited attention, although, substantial numbers of workers are experiencing the health effects of working outdoors in elevated temperatures and humid environments. The impacts of extreme heat exposure on workers' health, safety, and productivity have been discussed in this review article. The prospective health effects of such exposures are underestimated due to the underreporting of heat illnesses. More research studies need to be done in order to quantify the impacts of workplace heat exposure exacerbated by climate change in recent years.

* **Corresponding Author:** Dr. ijaz ahmad ✉ drahmadtarar@gmail.com

Introduction

Workers, especially those working outdoors, are often the first to be exposed to the effects of environmental conditions. They may be exposed for longer durations and at greater intensities which in the long-run could result in prevalence and severity of known occupational hazards and exposures. Literature has shown that increase outdoor temperature can cause outdoor workers to experience more frequent, intense, and longer exposure to UV radiation, resulting in an increased risk of adverse eye effects, skin cancer, and possibly immune dysfunction (Schulte and Chun 2009; Kiefer *et al*., 2014; Flouris *et al*., 2018). Besides, exposure to higher temperatures with more frequent periods of heat may result in greater heat stress, potentially leading to more cases of heat-related illnesses such as heat rash, stroke, cramp, heat exhaustion, Heat Syncope, and Rhabdomyolysis. Exposure to increased temperature can also result in reduced vigilance creating an increased risk of injury or lapses in safety. Furthermore, elevated temperatures can increase levels of air pollution, including ground-level ozone; outdoor workers have longer exposure to such air pollutants, which are linked to chronic health effects, such as respiratory diseases and allergic reaction (Kjellstrom *et al*., 2009; Nilsson *et al*., 2010; Gubernot *et al*., 2014; Campbell-Lendrum *et al*., 2015; EASAC 2019; ILO 2019).

During heat exposure, the heat gain in the body can be a combination of external heat from the environment and internal body heat generated from metabolic processes. There are two types of external heat exposure sources in the workplace: weather-related and man-made heat exposure. With predicted increasing frequency and intensity of heatwaves, weather-related heat exposure is presenting a growing challenge to occupational health and safety (Xiang *et al*., 2014).In the building industry, several contributing factors increase the risk of heat-related illness and injury. These include the constant use of machinery and powered tools, working on elevated surfaces, heavy workload, simple accommodation conditions near work sites, being temporarily employed by a sub-contractor on a daily payment basis, and constant and direct exposure to sunlight (Xiang *et al*., 2014). From 2003 to 2008, the US Census of Fatal Occupational Injuries recorded 196 heat-related mortalities and construction workers occupied the greatest proportion (36%) (CDC 2008). The process flow for studies inclusion for the article is given in figure 1 below. This review article focus on the impacts of extreme heat exposure on workers' health, safety and productivity and discuss in detail the characteristics and health effects of heat exposure among construction industry workers. Globally, the literature on the effects of scorching heat on the health of outdoor workers has received limited attention, although, substantial numbers of workers are experiencing the health effects of working outdoors in elevated temperature and humid environment.

Heat stress

Heat stress refers to heat received more than that the human body can tolerate, without physiological impairment (Kjellstrom *et al*., 2016). Heat stress effects can be described in three ways: internal body heat, external heat, and clothing heat from muscular physical activity, ambient environmental temperature, and body cloths heat convection and sweat evaporation respectively (Kjellstrom *et al*., 2016). The effects of exposure to heat from sun range from mild to severe depending on individual behavior. High levels of exposure to sunlight combined with weather conditions like humidity without a breeze in an enclosed area can lead to heat-related disorders or even severe cases like death, the factors along the casual chain of heat stress and illness are depicted in figure 2 below (Wang and Song, 2017). Frequent dehydration is a sign of heat-related illnesses, which can lead to fatigue as well as increased risks of injury.

Occupational exposure to heat stress

Studies have established that thousands of workers can become ill every year due to exposure to working environments characterized by high temperatures. Most of these people exposed to the high levels of

heat develop chronic illnesses while others become allergic to heat conditions (Wang and Song, 2017). Workers will tend to perform ineffectively when the working conditions are not favorable. Research proved that workers perform differently when exposed to diverse conditions when working in a hot environment, there is a high likelihood of heat increase because of the normal metabolic activities and heat from the sun (Venugopal *et al.*, 2016: Wang and Song, 2017).

Health effects

The direct health impacts of heat exposure are usually assessed in terms of mortality (Kjellstrom *et al.*, 2016) or hospital admissions. Elderly people and individuals with impaired health are especially vulnerable, but heatstroke also occurs among workers who perform heavy labor in hot conditions with potentially wider social and economic implications. The heat-related illnesses come from exposure to hot temperature or prolonged heat (Chan *et al.*, 2017).

The body meets expectations should cool itself under amazing or prolonged heat, blood rushes, and reach to the surface of the skin. Thus, less blood comes to the brain, muscles, and different organs. This could heart and interfere with both physical strength and mental capacity, leading, sometimes to risks that may damage the health, and cause the illnesses of heatstroke, heat exhaustion, heat cramps, heat syncope, heat rash, and rhabdomyolysis as indicated in the table 2.

Table 1. Heat stress index OSHA standards.

Risk	Temp°FWBGT	Risk Mitigation	Heat injury signs and symptoms
White flag minimal	< 82	Time to exercise Drink water/sports Before/after exercise	Recognize early symptoms and take appropriate action to prevent serious heat disorders in yourself and others.
Green Flag Low	82-84.9	Drink at least 1 qrt of water/sports drink every 20 min	Recognize early symptoms and take appropriate action to prevent serious heat disorders in yourself and others.
Yellow Flag Medium	85-87.9	Take rest breaks during exercise and keep drinking fluids	Heat cramps likely: painful contraction of muscles, weakness
Red Flag High	88-89.9	Consider reducing work out intensity	Heat exhaustion likely: Dizziness, nausea, vomiting, headache, fainting, disorientation, weakness
	≥ 90	Extreme caution Exercise indoors in a cooler setting	Heat stroke highly likely: Extremely high body temp, confusion, convulsions, unconsciousness, death

Some construction workers reported that those who experienced heat stress often had to stop working, and in some cases, the results were fatal. Therefore, thermal stress the major cause of health complications among construction workers (Venugopal *et al.*, 2016). The fatalities in thermal stress often increase during summer, when the temperatures are extremely high. Since most countries do not have heat stress regulation methods, heat prevention and treatment of symptoms could be an option that could help construction companies to deal with heat stress (Chan *et al.*, 2017). The effects of heat stress on the normal body functioning can be measured using the rate of heartbeat, body consumption of oxygen, expenditure of energy, fatigue, and minute ventilation (Guo *et al.*, 2014).

There exists strong evidence that heat has physical, psychological, and mental effects including exhaustion and skin burns, lowering of cognitive performance, loss of productivity, which may lead to skin cancer and thermal stress as indicated in figure 3 (Kjellstrom *et al.*, 2009; Yang 2017).

Heat stress control and exposure management

Heat stress control

Heat exposure is a widespread problem and anyone who works outdoors or in an open environment, even under a shade, without air conditioning is exposed to severe heat stress especially in hot summer.

Table 2. Some heat illnesses, their symptoms and effects.

Heat illness	Health effects and symptoms
Prickly heat, heat rash	Reduced heat tolerance; dysfunction of sweat glands; re-duced sweating capacity
Heat cramp	Reduced heat tolerance; muscle soreness, stiffness; reduced mobility
Heat stroke	Reduced heat tolerance; cel-lular damage in different organs, particularly in the central nervous system, heart, kidneys, and liver
Heat exhaustion acute	Reduced heat tolerance
Chronic heat (Months) exhaustion	Headache, Gastric pain, Sleep disturbance, Irritability, Tachycardia, Vertigo, Nausea
Chronic heat (Years) exhaustion	Hypertension, Reduced libido, Sexual impotency, Myocardial damage, Nonmalignant diseases of the digestive organs Hypochromemia

This includes not only the construction sector but agricultural workers, road cleaners and municipality, window cleaners, fueling and service station attendants etc. (Venugopal *et al.*, 2016). Employers have a legal and moral responsibility to protect their employees and should provide the training and awareness as well as adequate protection for all those who are vulnerable to this challenging worksite hazard and risk. Not only employers but managers, supervisors, and even workers do have a shared responsibility.

Table 3. Worksite practices as recommended by the Standard Advisory Committee on Heat Stress of OSHA.

Compulsory for all jobs	Special practices for outdoor hot job	Special practices for extremely hot exposures
Adequate water supply	Engineering controls	Duration of exposure time regulated by experienced workers' judgement (freedom to interrupt work during extreme discomfort)
Acclimatization	Work-rest regimen	Preplacement and periodic medical examination (also re-quired in any hot job if work load is heavy)
First-aid training	Additional acclimatization	Observation by trained supervisor
Training of workers for health and safety procedures and work practices	Adaptive work scheduling	Protective clothing (mandatory)
In case of heat illness, the WBGT a must be assessed on the site	Protective clothing and/or equipment	
	Freedom to interrupt work during extreme discomfort	

It is the responsibility of employers to raise awareness of this issue and provide adequate facilities and resources to control this important occupational hazard (Yang 2017). To adequately address heat stress it is best to manage this holistically and implement a variety of measures including but not limited to.

Assessment of the onsite risks and determination of hazards.

Implementation of suitable effective engineering control measures.

Implementation of an effective heat stress program for workers effected by heat stress.

Implementation of Mid-day break, working hours, facilities provision regulations during the summer months for outside employees.

Heat stress management programs

Employers must perform a risk assessment, to identify high temperature working environments and implement effective controls to reduce exposure and protect employees from heat exposure as far as is practical. Employers that have employees working in

high temperature environments shall develop a heat stress program that will consist but not be limited to the following elements:

Acclimatization programs should be put in place, in case of working in hot climates for new, on vacation workers, and the workers moving from normal climate worksites to hot ones with an allowance of five to seven days for acclimatization before starting hard work in a hot environment in summer.

The environmental heat stress and exposure shall be managed by assessing environmental conditions and by putting proper control measures. Thermal Work Limit (TWL) index should be adopted and linked to control zones with specific requirements to manage thermal exposure and stress.

An effective communication system need to be established with all gadgets for informing/reminding employees and visitors, regarding high-temperature sites including signs and symptoms of heat stress. Also the communication of current environmental conditions to employees so they can take the appropriate actions to prevent heat stress injuries and illnesses should be part of such systems.

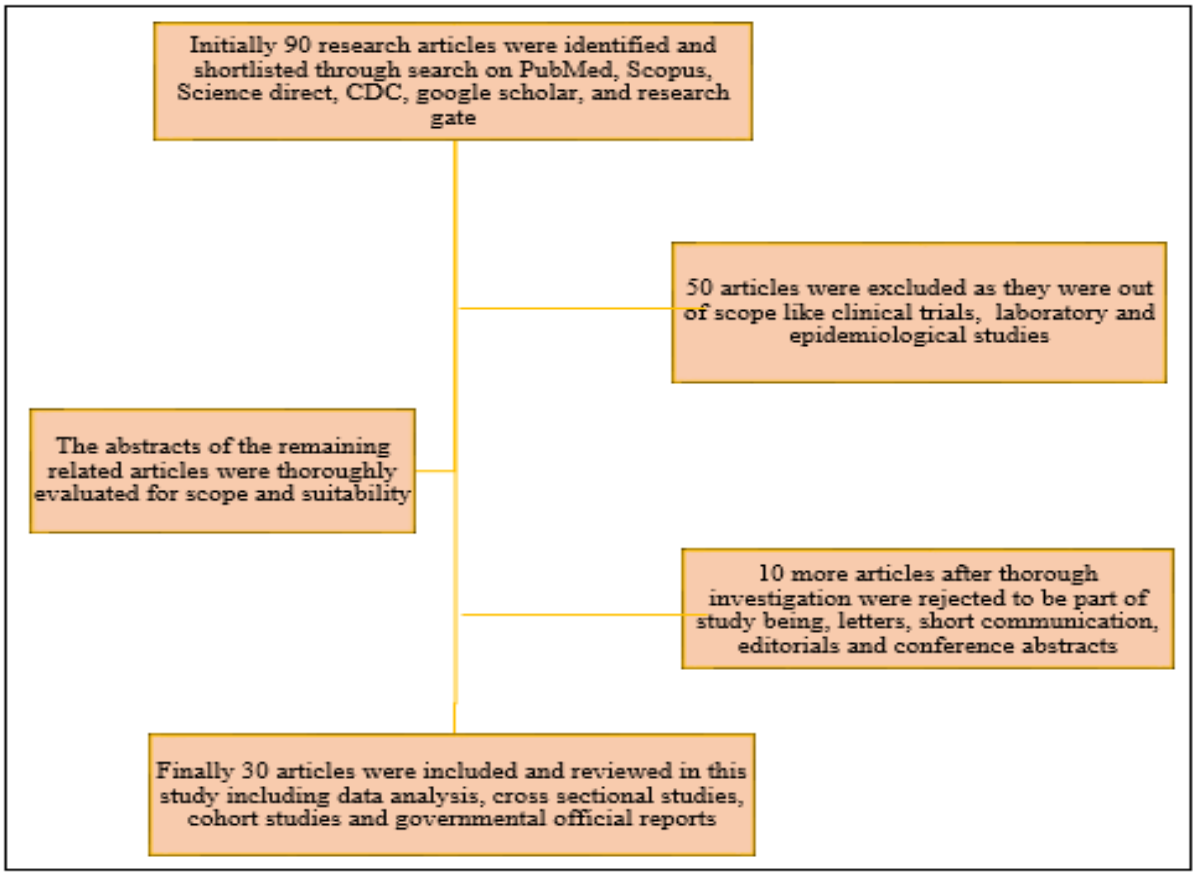

Fig. 1. Process flow for studies inclusion in this study.

Provision and easy access to facilities like drinking water, a large water bottle, shade, washrooms, showers, rest and break area for high-temperature environments should be ensured.

Provision of appropriate cotton made loose-fitting, thin and light color body cooling devices, a personal umbrella, and PPEs shall be ensured.

Training and awareness

Employers have a responsibility to raise awareness of the dangers of heat stress and the precautions to be taken to protect the workforce from heat stress and heat illness. General working in heat awareness should be undertaken to cover:

Sufficient legible information in form of posters,

leaflets, training videos and presentations given to workers regarding thermal stress, heatstroke, extreme heat conditions, working safely, dehydration symptoms should be displayed in common places like toilets etc.

Employees should be trained on identifying the signs and symptoms of heat injuries illness, the importance of hydration, intake of balanced healthy diet and fluids, rest breaks, monitoring of hydration levels, wearing of PPEs including clothing, calling of first aiders, employers heat stress program.

First Aiders should be trained on how the body overheats and how to recognize the signs and symptoms of heat related illness and the different types of heat-related illness.

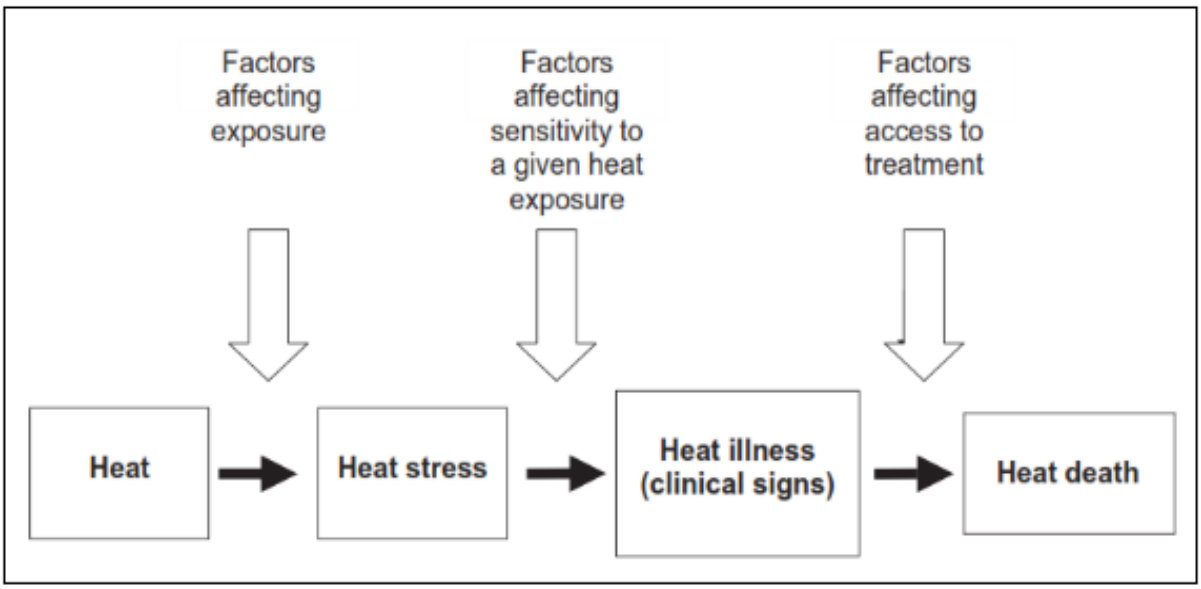

Fig. 2. Factors along casual chain of heat stress and illness (Sari and Hajat 2008).

Personal protective equipment and worksite facilities

The strategies may be employed to minimize the impacts of heat stress on workers including shortening of working hours, job rotation, frequent rests and drinking water, improvement of ventilation, installing thermal barriers, and provision of air conditioning facility (Wang and Song, 2017). While working outdoors in direct sunlight, workers should try minimizing exposure to heat and sun using sunscreens, wearing light clothes, putting on goggles and hats, and working under movable shades (Yang, 2017).

Studies have identified exposure to sunlight as among the cause of heat-related diseases. Thermal stress is among the leading heat-related illness and prolonged exposure to the sun without breaks, cold drinks, and breezes. The performance and effectiveness of an employee are related to the condition of the workplace. When the workplace is not conducive, prolonged working hours are not recommended because of the related health effects as well as reducing risks of injuries. From the available literature, it is evident that direct sunlight exposures among workers is among the major causes of reduced efficiency, acute heat stroke, and workplace accidents.

Anti-heat stress clothes

Anti-heat Stress clothes like ventilation garments, double layer clothes, hybrid cooling vests, anti-heat stress uniforms are discussed in the literature for their effective use and reducing heat effects on workers. Chan *et al.*, (2017) highlights that the use of jackets reduces the effects of heat and hence giving relief to workers at construction sites. It is important for workers in construction sites and other extremely hot conditions to put on cooling clothing with ventilation fans, as well as having openings in

workplaces help the free circulation of air. The clothes having ventilation fans will help take away the heat from the body and prevents the heat stress-related complications in workers on construction sites (Rowlinson *et al*., 2014; NIOSH, 2018).

In double-layered clothing solar radiation affects the outer clothing surface at most while the inner layer remains cool due to convection effect.

The inner air gap between clothing and skin influence the thermal insulation and subsequently provide the thermal comfort of humans (Yang 2017; Shimazaki *et al*, 2017). Fan-based cooling vests that are battery-driven having phase change materials like ice, frozen gels in vests are successfully employed for outdoor construction workers to combat heat stress. However, the effectiveness and applicability of these products in the construction industry have yet to be verified (Guo *et al*, 2017).

The appropriate anti-heat stress uniform made from fabric and special materials can resist the high temperature and allow permeability during sweat (Chan *et al*, 2017). The Standard Advisory Committee of Occupational Safety and Health Administration, USA has issued recommendations for minimization of heat stress at worksite some are given in table 3.

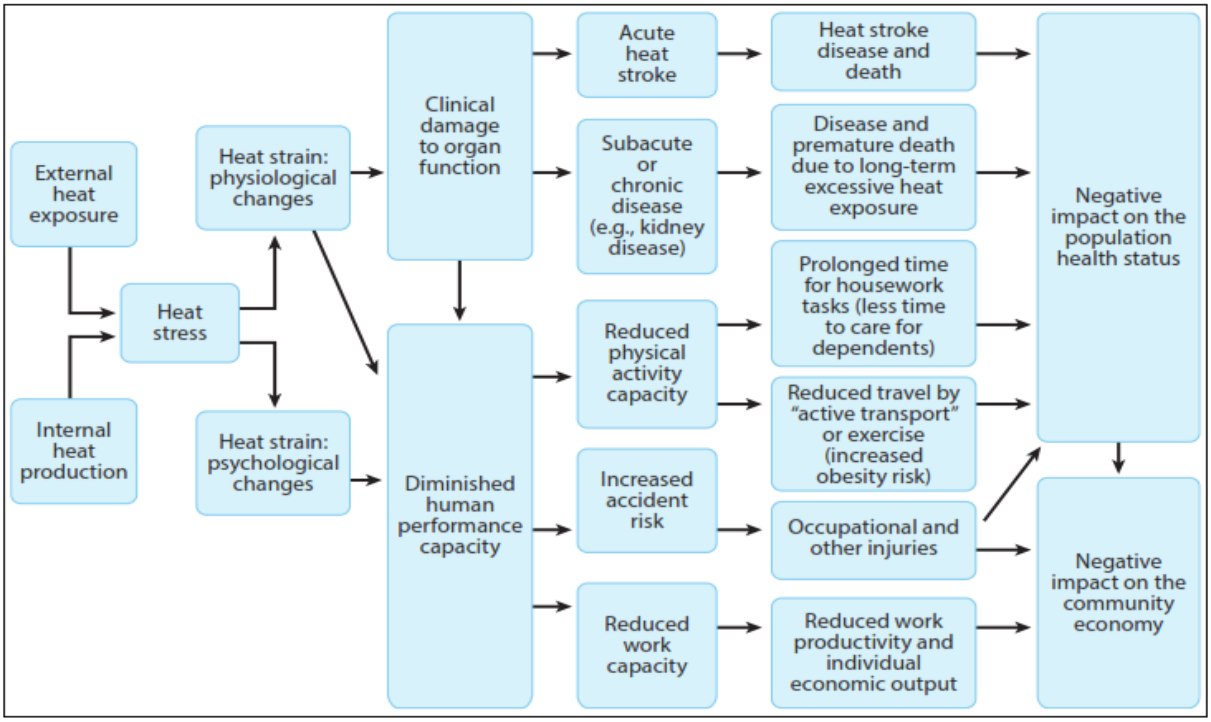

Fig. 3. Casual frame work of direct heat exposure health effects on workers (Kjellstrom 2015; Tord etal; 2016).

Case of Jeddah, Saudi Arabia

The construction industry is considered one of the top and the rapidly growing industries in the Kingdom of Saudi Arabia and especially in Jeddah, which also requires recruiting a huge number of migrant workers. According to weather reports, temperature could reach up to 49.4˚C during summer in Jeddah city, which can make workers exposed to heat stress while working in the construction industry. The local harsh atmospheric weather conditions, dust storms, obstructive buildings, arid environment, least precipitation rate, exhaust emissions, hot summers, power generation, high temperature, humidity, debris and demolition materials, fewer herbs and plantation are aggravation factors for the working population, especially the migrant outdoor construction workers (Ahmad *et al*., 2017a, 2017b: Balkhyour *et al*., 2019, Ahmad and Balkhyour 2020: Serdar *et al*., 2019).

Global warming has been attributed to the rising temperatures in most parts of the world. The Kingdom of Saudi Arabia has had an increase in

temperatures as a result of global warming (Ayyappan *et al.*, 2009). The meteorological data shows that the country has witnessed extremely high temperatures spells i.e. about 50°C in recent years (Statista, 2016), which describes the intensity of heat stress among outdoor workers (Almazroui *et al.*, 2012). Long term exposure to heat stress along with outdoor high temperatures results in excessive fluid loss, shock, or heat stroke. However, these effects have never been studied extensively, and there is dearth of literature regarding safety procedures, and control measures among construction industry workers. At present, Saudi Arabia lacks broad spread legislation regarding occupational safety and health, although some basic OSH rules have been chalked in Labor Law, also Ministry of labor ratified some ILO rules (Balkhyour *et al.*, 2019, Ahmad and Balkhyour 2020).

According to Saudi Gazette reports about 85 percent of work-related injuries have taken place in three major economic sectors like construction, trade and downstream industries. According to the latest statistics published by the General Organization for Social Insurance (GOSI), during the third quarter of 2015, 13, 846 workplace injuries were reported, of which 7,179 injuries were reported in the construction sector only. The social insurance law was amended by the Royal Decree No. M/33 dated 29/11/2000 and implemented as of 01/04/2001.The GOSI was established to implement the provisions of the Social Insurance Law and follow-up the process of achieving the compulsory insurance coverage, collecting contributions from employers and paying benefits for the eligible contributors or their family members.

Conclusion

From the studies considered its evident that safety and health in the construction sector are influenced by three significant factors i.e. management, the human resources office, and the workers. The administrations did not have persuasive and strategic plans and did not allocate specific budgets for this purpose. Also, the human resource offices is seemed to be ineffective most of the time as they don't hold required health and safety meetings, training and awareness programs, don't arrange and provide sufficient first aid and personal protective equipment. Lastly the worker's attitude, behavior, ideas, perceptions, and beliefs are another factor in shaping workers orientation toward safety, hazards, and risks. Most importantly, the role and behavior of supervisors and managers are also questionable, their observance and vigilance is nothing but silent spectator most of the time, as they inclined toward more work done rather than safety and health of workers.

There is a need for the development of appropriate surveillance programs, thus enabling the proper assessment of occupational heat exposure and related injury and illness. The further studies should concentrate more on effect of the social insurance and it is relationship with the safety, socioeconomic status, and estimating the exact nature of thermal load experienced by workers and its marked effects. There is a need to conduct more research about the use of the anti-heat stress uniforms, occupational exposure to heat stress, its health effects, and controls among construction workers in Jeddah city. Comprehensive national research strategy, public OHS research institutes, strong and effective research capacity, a dedicated research budget, and long-term arrangements to secure research activity are also recommended.

Conflict of interest

Declared None.

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Author's contributions

Tarek Abokhashabah being the lead author conceived the idea and drafted this review. Prof. Bassem Jamoussi and Dr. Ahmed Saleh Summan wrote the

introduction, and central parts of the paper, Dr. Ezz Abdelfattah review and proof read the manuscript while Dr. Ijaz Ahmad assisted and coordinated the editorial process.

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