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Review

Occupational Injuries and Accidents in Work Environment's Heat Stress Exposure: A Systematic Review

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Abstract

Background: activity in hot environments is among the most common physical dangers in work environments that not only creates diseases resultant from heat which influences on staff's health but also increases job injuries and accidents. Job injuries, diseases, and reduction in workers' efficiency in exposure to heat stress have caused increasing anxiety. Most of the study results are demonstrative of diseases as a result of heat and less related to job injuries and accidents. Therefore, the present study aims at reviewing previous studies in the field of job injuries and accidents in exposure to the work environment's heat stress. **Methods:** this review study has systematically reviewed publications and articles from 2000 to 2019 in databases. Keywords including "heat stress", "heat strain", "heat exposure", "heat wave", "heat injuries", "job accidents", "job exposure", "hot environment" and "air change" have been used and finally, 30 articles included into the study. **Results:** study articles consist of 29 jobs and 1 military environment. Study occupations consist of one study about military forces, textile, aluminum smelting, cleaners of oil reservoirs, two studies about mineworkers and metal and iron industries, three studies about building workers, four studies about agricultural workers and 15 studies about different occupations. Also, 11 studies conducted in open environments, seven studies in closed environments and 12 others conducted both in open and closed environments. 17 analytical studies, three correlational, cross-sectional, cohort studies, one cohort, and descriptive study and two descriptive-analytical studies have been conducted. Most job injuries and accidents happened during summer and men especially the young have involved in such problems and job injuries and accidents have increased due to extreme temperature increase. Generally, job injuries and accidents include burn, slip, collision with things and collision with mobile things. **Conclusion:** there is a strong relationship between temperature in hot environments and risk increase in injuries and accidents of work environments which differ based on employees' features (such as age, gender, occupation, and industry). However, dominant mechanisms on the happening of such injuries have not been determined yet. It necessitates more expertise to determine especial injuries and accidents happening in hot environments. Policymakers and employers have to be more aware of job injuries and accidents in heat exposure and suitable educational resources have to be provided to prevent such injuries.

Keywords: Heat; Heat stress; Heat injuries; Job accidents; Heat wave

Introduction

The earth temperature increase has increased heat loads in open and closed environments which not only threatens the health of society individuals but also disrupts health, continence, and comfort of workers in hot environments especially employees in open environments. In open work environments, direct sunlight exposure besides

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destructive sanitary and health effects causes humans' performance failure in work conditions.[1-3] Workers in different industrial sections such as agriculture, forestry, fishery, and construction are exposed to external heat stress and sun heat which have undesired effects on workers' health. Moreover, workers in hot environments without air conditioning like metal smelting industry, foundry, steel, bakeries, laundries, and caterings are also affected by these hot conditions and encounter with undesired effects of heat.[4, 5] In such occupations besides external heat exposure especially during hot seasons in hot and dry areas, heat is created in the body while doing physical actions which results in the in-depth temperature of the body and consequently affects health, performance, and efficiency in individuals.[6, 7] Diseases related to heat including heat cramps, heat syncope, fatigue, heatstroke, heat faint and shock are mostly due to undesired effects of heat on human health.[8] Such effects are also reported among work environments like ground mine workers, building workers and agriculture workers.[9-13] There are many studies show that heat exposure may cause job injuries on workers.[14-19] As well as heat diseases in work environments, working in such environments may increase the risk of job injuries and accidents.[20, 21]

In low and medium-income nations, reduction in efficiency is more expected due to weakness in providing desired environments to work in open and closed places.[1, 22] The short term extreme heat exposure (extreme exposure) can increase body depth temperature and it directly causes diseases related to heat such as slight heat rashes, muscular cramps, heat fatigue, and health-threatening heat shocks. Long term and chronic effects of heat exposure in work environments are also reported including cardiovascular diseases,[23] effects on mental health[24] and chronic kidney diseases.[25, 26] Statistics in Australia have shown that there are 485 disease and injury cases related to working in environments with heat exposure from 1997 to 2007.[27] Hobler and his colleagues evaluated the effects of climate changes in Germany, results showed that temperature above 20°C reduces human efficiency 3% to 5% which this amount reaches to 75% in temperatures between 35°C to 37°C.[28] Heat stress in the environment changes an individual's cognitive performance through inconvenience, cognitive fatigue, agitation and faint in high temperature.[29] Humans have two reactions in response to their inner temperature increase:

a) Behavioral responses for example reduction in physical activity, putting out clothes and distancing from the source of heat
b) Cognitive responses (reduction in focus and error increase).[30]

Stubblefield and his colleagues have measured active hyperthermia effect resultant from a heat stress experiment on individuals' four cognitive performances (working memory, attention, response speed, processing speed), findings revealed that hyperthermia reduces working memory performance, previous studies showed that response speed, processing speed, and attention are less influenced by the effects of body depth temperature.[31] The conceptual distribution chart of human performance with different amounts of WBGT Index exposure demonstrates that higher than 25°C WBGT human's working capacity reduced and in higher than 40°C WBGT will be difficult for everyone to have physical actions.20 However, the probability of injury happening in hot weather conditions is not obvious and it may cause a significant humane and economic cost when accompanying effects related to heat. In the US, the National Institute of Occupational Safety and Health (NIOSH) estimated that around 5 to 10 million workers work in hot weather conditions.[32]

Estimating results of employing workers population in Iran open areas based on Iran's Statistics Center was around 8550500 individuals in different occupations who are working in the open areas and are exposed to direct sunlight and effects of global warming. This information and statistics represent little information regarding the importance of this issue and also it seems that these statistics are related to injuries of heat such as falling and accident resultant formwork. Therefore, the relational emergence of job accidents and injuries resultant from heat is obscure. Hence, the purpose of the current study is to review the previous studies in the field of job injuries and accidents in heat stress exposure in the working environment.

Methods

All English and Persian studies related to heat and resultant injuries systematically investigated in Iran Scopus, Magiran, Google Scholars, Pub Med, ScienceDirect, Web of Science, SID and Medex bases from 2000 to 2019. Keywords including "heat stress", "heat strain", "heat exposure", "heat wave", "heat injuries", "job accident", "job exposure", "hot environment" and "air changes" have been used to search. Also, the studies included in this study were:

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- Authentic studies in English and Persian published from 2000 to 2019.
- Studies have investigated the relationship between heat and it resultant injuries and accidents

Exclusion criteria from the study were focusing only on resultant injuries from work due to heat exposure. Review studies, editorials, cover letters, presented articles in seminars and reports excluded from this study. Based on the study purpose the total number of 30 articles has been investigated. Study selection flow diagram is presented in Figure 1.

Results

Most of the investigated articles have been conducted in developed nations such as North America, Australia and tropical and less developed areas of Iran, India, and Thailand. Study articles consist of 96.6% occupational environments (n = 29) and 3.4% military environments (n = 1). Study occupations consist of 3.3% military forces (n = 1), 3.4% textile workers (n = 1), 3.4% aluminum smelting workers (n = 1), 6.6% mine workers (n = 2), 6.6% iron and metal industry workers (n = 2), 10% building workers (n = 3), 3.4% clean workers of oil reservoirs (n = 1), 13.3% agricultural workers (n = 4) and 50% other occupations (n = 15). Also about the study environment, 40% in open environment (n = 12), 23% in closed environment (n = 7) and 27% both in open and closed environments (n = 11). Used factors in this study consist of 23% minimum and maximum temperature (n = 7), 10% moisture index (n = 3), 10% air temperature (n = 3), 20% WBGT Index (n = 6) and 37% heat exposure as the risk factor (n = 11). Methods of evaluating the relationship between heat exposure variables and job accidents risk consist of 57% analytical study (n = 17), 10% correlational study (n = 3), 3.3% cohort study (n = 1), 10% cross-sectional study (n = 3), 10% case-crossover study (n = 3), 6.6% analytical-descriptive study (n = 2) and 3.3% descriptive study (n = 1). Cross-sectional, case-crossover and correlational studies consist of nonparametric regression models such as Generalized Estimating Equations (GEEs), Generalized Additive Model (GAM), Negative Bias Regression (NBR) and parametric regression models. Results showed that most job injuries and accidents happened during summer and men especially the young have involved in such problems and job injuries and accidents have increased due to extreme temperature increase. Generally, job injuries and accidents include burn, slip, collision with things and collision with mobile things. Usually, heat moistens the palms, steams goggles, decentralization, and dizziness which increase the number of accidents. The following table shows a summary of articles in explanation and kind of study and key results.

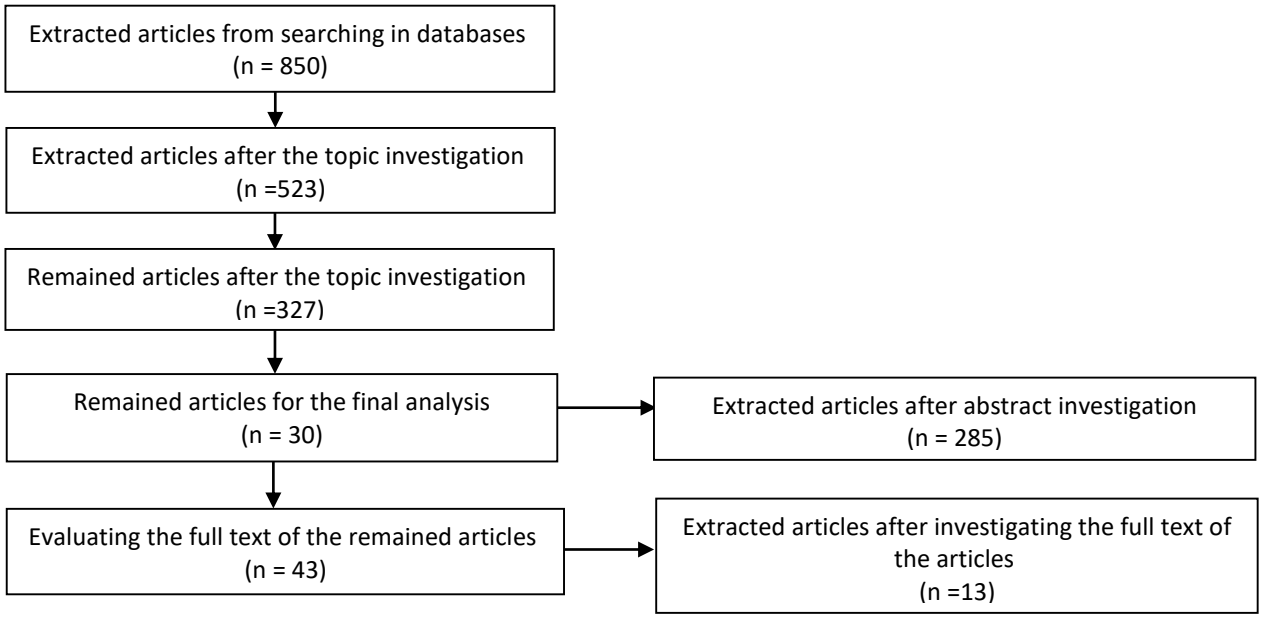

Figure 1. PRISMA flow diagram showing the different phases in searching relevant publications

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Table 1. A summary of articles including target workers, type and environment of study and key results

Row	Target workers	Study type	Study environment	Stress index	Results
1	Different occupations workers	analytical	Open and closed	Heat exposure as a risk factor	Besides diseases resultant from working in hot environments, working in such environments may increase the risk of job injuries and accidents[10]
2	Building workers	cross-sectional survey	Open	Heat exposure as a risk factor	12.8% of workers have suffered from job injuries and accidents which 9.2% and 14.7% of them have occurred during summer and winter respectively. Workers with less than 36 months of working experience have experienced job injuries and accidents. Job injuries and accidents include slight cuttings, scratches, and slight injuries, breaking and falling[11]
3	Different occupations workers	analytical	Open and closed	Daily T_{max}	Most accidents happened during the days with higher than 25°C[15]
4	Aluminum smelting workers	analytical	Closed	HI- 11 thermal categories Considered relative humidity	Workers have suffered from severe injuries exposing to heat. Happening of severe injuries in 33-38 and above 38 degrees centigrade equal with 2.28 and 3.52 odds ratio respectively[19]
5	Different occupations workers	analytical	Open and closed	Heat exposure as a risk factor	Usually, heat moistens the palms, steams goggles, decentralization, and dizziness which increases the number of accidents. An increase in body depth temperature has negative effects on the reduction of body water, negative effects on individuals' behavior such as physical fatigue, irritability, lethargy, incorrect judgment, conscience reduction, agility, concentration, and coordination reduction[20]
6	Different occupations workers	analytical	Open and closed	Heat exposure as a risk factor	Working in hot environments may increase the risk of job injuries and accidents[21]
7	Open occupations workers	Analytical descriptive	Open	WBGT	The most percent of performance reduction observed in occupations with 500w consumed energy during July. The average difference in the percent of performance reduction of 500w occupations was statistically meaningful for environmental parameters such as air temperature[22]
8	Different occupations workers	Cohort study	Open and closed	Heat stress measure:"never"," sometimes "and "often"	Increase in job injuries and accidents in hot environments for men and women equaled with 2.12 and 1.89 odds ration respectively. The prevalence of heat exposure injuries includes imbalance (24%) and falling (18%)[25]
9	Military forces	Correlation	Open	Average T_{max} and Minimal dry bulb temperature	Prevalence of injury and accident is higher during summer than fall. Men are more sensitive to heat exposure injuries and accidents. Correlation between Average T_{max} and time waste injuries and other injuries is 0.92 and 0.96 respectively[32]
10	Coal mine workers	analytical	Closed	Heat exposure as a risk factor	28.5% of job injuries and accidents happen due to heat exposure with a 1.35 odds ratio[33]
11	Different occupations workers	analytical	Open and closed	Heat exposure as a risk factor	61.8% of heat exposure cases have increased job injuries and accidents with 2.29 odds ratios[34]
12	Different occupations workers	Correlation	Open and closed	Daily T_{max} Considered relative humidity	There was a linear algorithm relationship between job injuries and accidents and heat. An increase in Daily T_{max} may increase labor compensation requests by up to 0.2%. Heat exposure job injuries and accidents include

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					falling, collapsing, collision with things and harmful materials exposure[35]
13	Different occupations workers	cross-sectional	Open	Heat exposure as a risk factor	25.9% of workers have suffered from job injuries and accidents have exposed to heat. Job injuries and accidents include burn (54.1%), slipping (44.3%), collision with things (27.8%) and collision with mobile things (10.3%). 25.2% of workers have witnessed that their colleagues suffered from job injuries and accidents when working in hot environments including falling and slipping (55%) and burn (42.3%)[36]
14	Textile industry workers	analytical	Closed	Heat exposure as a risk factor	The prevalence of accidents has significantly increased during the summer months[37]
15	Metal and iron industry workers	cross-sectional study	Closed	Heat exposure as a risk factor	Prevalence in job injuries and accidents was 18.7% more than among workers who work in heat exposure rather than those who don't work in heat exposure[38]
16	Agriculture workers	Case-Crossover Study	Open	Maximum daily humidex (HX)	In environments with more than 33 HX Index, the risk of happening traumatic accidents and injuries increases. Traumatic injury in environments with 25-29, 30-33 and more than 33 HX Index concerning ≤ 25 HX Index have increased with 1.14, 1.15 and 1.01 odds ration respectively. The most traumatic injuries have observed during June-July among cherry harvesters[39]
17	Different occupations workers	case-crossover study	Open and closed	Daily T_{max} and T_{min}, Included relative humidity	There was a positive relationship between temperature degree and injury. There was no linear relationship between T_{max} and injuries and their relationship is a curved shaped one. Vulnerable workers include young workers, men, and workers with high physical demands[40]
18	Employing workers in a hot industry	analytical	Closed	WBGT	There was not a meaningful relation between test duration, reaction time and error numbers in 1 and 2 Stroop tests but the above-mentioned variables have a direct and meaningful relationship with heat in Stroop test 3. Test duration, reaction time and error numbers in Stroop test 3 (heat exposure group) were meaningfully higher than heat non-exposure)[41]
19	Building workers	Analytical descriptive	Open	Daily T_{max} Daily T_{min}	There was no meaningful relationship between accidents and almost hot environments. The cost of big accidents for workers older than 55 years old was more than new workers during heat exposure. Vulnerable groups in this study include experienced workers, male workers, workers between 35 to 55 years old, workers of small and medium industries and workers employed in carpentry, electricity, mechanics and setting operator[42]
20	Rice farms workers	analytical	Open	WBGT	Heat may influence performance reduction, safety, and efficiency and reduce efficiency and increase in the accidents among agriculture workers[43]
21	Metal and iron industry workers	analytical	Closed	Heat exposure as a risk factor	98 out of 217 workers who have exposed to heat (77.2%) have experienced job injuries and accidents. There was a meaningful relationship between work environment temperature and job injuries and accidents[44] ($X2 = 33.97$, $df = 1$, $P<0.0001$)

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22	Oil reservoirs cleaning workers	analytical	Open	$WBGT_{max}$	Happening sever and chronic heat injuries have meaningfully increased in $WBGT_{max}$ higher than 20°C with 1.06 and 1.4 odds ratios respectively[45]
23	Different occupations workers	Correlation	Open and closed	Daily T_{max} Daily T_{min}	There was a direct relationship between Daily T_{max} and complaints about job accidents. There was a 20% increase in job injuries and accidents per degree of centigrade of T_{max} until 37.7°C. There are not delay effects in higher than the threshold temperature[46]
24	Different occupations workers	analytical	Open	Daily T_{max} Daily T_{min}	A 6.2% increase in labor compensation requests for workers who work in open hot environments and have suffered from job injuries and accidents[47]
25	Different occupations workers	analytical	Open and closed	Air temperature	In temperatures above 35°C workers' health and efficiency reduced, on the other hand in 40°C efficiency in hard occupations reduced and the rate of accidents increased[48]
26	Crops workers	descriptive	Open	WBGT	The most performance reduction and the least performance reduction related to plowing and weeding respectively. Total performance reduction was 63.9% for cropping per hour due to high physical activity in the work environment and working in an open environment and exposing to direct sunlight which leads to heat stress to workers[49]
27	Underground mine workers	analytical	Closed	WBGT PSI HSSI	There was a high correlation between PSI Index and perceptual effort during a long term activity (60 min) with perceptual effort. There was a good correlation between workers' dissatisfaction and an increase in sweating in hot environments. Physiologic and perceptual responses were meaningfully influenced by heat[50]
28	Different occupations workers	analytical	Open and closed	Air temperature	In areas with a temperature above 40°, C workers may experience a wide range of heat exposure effects such as sunburn, sleeplessness, irritability, and fatigue which lead to problems in working efficiency and extreme reduction in production and increase in accidents[51]
29	Building workers	analytical	Open	Air temperature	Climate changes and global warming potentially reduce both human health and production level[52]
30	Agriculture workers	A Case-Crossover Study	Open	Maximum daily Humidex	For amounts of maximum daily, the humidex of 25-29, 30-33 and more than 34 in comparison with less than 25 have increased physical injuries with 1.14, 1.15 and 1.10 odds ratio[53]

Discussion

The purpose of the present study is to investigate previous studies in the field of heat stress in different countries regarding job injuries and accidents in work environments heat exposure. Heat as a vital factor has gained considerable attention for a long time ago. Heat in industries is considered a harmful factor with an energy source in production processes and it may harm workers' health. Heat is an undeniable danger in work environments, especially in developing nations. Global weather has lost its balance during the 2oth century especially within two recent decades and it is inclined to temperature increase. However, predictions for the 21st century alarmed global temperature increase due to greenhouse gases increase. The magnitude of predicted temperature increase to 4.5°C until the end of the present century may potentially cause problems. In this way, heat exposure creates job injuries and accidents for workers in open and closed environments.14 26% of the studies have

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conducted in closed environments including iron and metal industry, aluminum smelting, mine and textile, workers in closed environments with unsuitable air conditioning are exposed to the risk of heat injuries and accidents, this risk increases in environments with ovens, hot machines, melting metals and furnaces due to reflected radiances and radiant temperature increase.

Nag and his colleagues have conducted a study in the textile industry, the results showed that accidents prevalence have considerably increased during summer months[33] Chau and his colleagues showed that 28.5% of job injuries and accidents were related to heat exposure with 1.35 odds ratio.[34] Results of the studies conducted in iron and metal industry workshops showed that the prevalence of job injuries and accidents was 18.7% more among the workers have exposed to heat rather than those who haven exposed to heat.[35] There was a meaningful relationship between work environments temperature and job injuries and accidents[36] and underground mineworkers' physiological and perceptual responses were meaningfully influenced under heat.[37] 23% of the studies have been conducted in open environments including construction, military forces, forestry, fishery, water, electricity, gas industries, agriculture and farms, these types of workers are exposed to direct sunlight and extreme heat while working in the open air during hot seasons. Besides unsuitable atmospheric conditions, heavy body activity and resultant heat from production mechanisms contain 80% of resultant heat from body activity and mechanisms and 20% of received heat from the environment. Study results out of open environments revealed that workers with less than 36 months working experiences were more intended to job injuries and accidents in summer,[10] prevalence of injuries and accidents is more in summer than in fall and men are more vulnerable to such injuries and accidents in summer,[38] also labor compensation request 6.2% increased for workers who work in hot open environments and suffered from job injuries and accidents,[39] 25.9% of workers who have suffered from job injuries and accidents have been exposed to heat [40] and work in higher than 33 HX Index environments, the risk of traumatic injuries and accidents has increased[41, 42] and per percent increase in WBGT causes 13% increase in extreme accidents and injuries,[43] there was not a meaningful relationship between accidents and hot environments,[44] usually heat moistens the palms due to sweating, steams the goggles, reduces focus and causes dizziness that all of them have increased the number of accidents, [45, 46] also heat may influence on reduction of performance, safety and efficiency and performance reduces and accidents increase among workers who are exposed to heat.[, 47-51]

Working in hot environments may increase the risk of job injuries and accidents [52, 53] and parameters of test duration, reaction time and number of errors in Stroop test was meaningfully higher in exposure group (heat exposure) than non-exposure one[54] and most of the accidents have happened in days with temperature above 25°C.15 13.3% of studies conducted on farmers and agriculture workers, agriculture is among the oldest productive industries and the most important economic activity. Farmers suffer from undesired effects of heat stress due to working in open environments. Since agricultural activities are conducted in hot seasons of the year, so heat stress is one of the factors which influences on health, safety, and efficiency of the workers.[37] Accordingly, agricultural activity is one of the activities with the highest risk of heat injuries and accidents. In the absence of safety and occupational health plan for protection, farmers are exposed to long term extreme heat. The agriculture industry has third ranking in death due to heat in America and death in this industry is 20 times more than non-military forces.48 6.6% of the studies conducted on mine workers, working in hot environments of mine is so common. Heat exposure in open mines is similar to open environments; but underground mines dependent on depth increase and resultant heat from untouched rocks, have caused heat stress problems.[55]

Usually, heat moistens the palms, steams goggles, decentralization, and dizziness which increase the number of accidents. Increase in body depth temperature has negative effects on reduction of body water, negative effects on individuals' behavior such as physical fatigue, irritability, lethargy, incorrect judgment, conscience reduction, agility, concentration, and coordination reduction which influence on performance reduction, safety, and efficiency.[44] Fogleman and his colleagues (2005) have studied aluminum smelting factory, the results showed that individuals who work in hot environments with a heat index above 32°C and suffer from heat injuries have 2.3 odds ratio.[19] Morabito and his colleagues (2006) studied hospitalized patients in hospital, the results showed that the most number of accidents have occurred in days that individuals were working in so hot environments[15] in this way Xiang and his colleagues (2014) have studied the relationship between hot environments and

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accidents from 2001 to 2010 and argued that those who work in hot environments suffer from mental judgment and memory deficiency. Also, sufficient information to estimate work accidents have not been mentioned. This study showed that a per percent increase in temperature may cause at most 0.2% increase in injured workers' complaints to 37°C and then injury danger has significantly reduced.[48]

In both conducted studies in Adelaide and Quebec, vulnerable groups have been identified including men, young workers (less than 24), open environment workers, occupation and industry workers, intermediaries and small and medium workers.[35, 48] Also, McInnes and his colleagues have shown that there is more risk in female workers and young workers (25 to 32) and elderly workers (55 and above) who have requested physical activity and exposed to heat.[41] Results showed that days with 32 to 37 degrees of the centigrade increase the risk of accidents to 8.2% and days with more than 37°C the risk of accidents has increased by 30%. In temperatures between 15 to 21 degrees of centigrade injuries and accidents have increased by 4% and 30% respectively.[56] Several results studies by Spector and his colleagues (2016), Hilles (2012) and Garson and his colleagues (2016) utilizing Humidex and WBGT Indices showed that in higher temperatures the risk of injuries has increased.[39, 45, 57] A study conducted among military personnel showed that the prevalence of injuries is higher in summer than in fall and dose relationship-response between emergence and average of maximum daily temperature was observed.[58] Concluding studies in India, France, and Australia showed that injury prevalence has increased from 9.2% to 49% among workers who are exposed to high temperatures.[10, 33, 34, 36, 39, 59] Moreover, a large scale cohort national study conducted on 58495 individuals in Thailand and results showed that there is a strong relationship between heat stress and job accidents. In this study, heat stress observed in 20% of workers who have more chance in their job accidents. Surprisingly, variables such as age, income, education, disease, alcohol consumption, smoking state, sleeping hours, place and type of work have been confirmed.[14] The heatwave is a long term hot weather that may contain high moisture. This expression is referred to as heat routine weather changes and also heat extraordinary changes that may happen once in a decade. A study conducted in Southern Adelaide, results showed that there is a meaningful relationship between heat wave and workers' complaints and also there is a direct relationship between Daily T_{max} and job accidents complaint. Job injuries and accidents have increased by 0.2% per increase in the T_{max} degree of centigrade until 37.7°C and severe injuries such as wounds, lacerations, amputation, and burn are relayed to heat waves.[60] A cross-sectional study in Adelaide on building workers showed that the severity of work accidents and injuries depends on workers' characteristics, type of work, work environment and direct cause of the injury. They reported that during these periods, building engineering workers, elderly workers and those who work in small companies are more exposed to the risk of severe accidents.[43] In some studies, the risk of injuries including “slipping, stumbling and falling”, “harmful substances exposure”, “collision with things and equipment”, “hitting things”, “sharp points”, “wound”, “explosion”, “burn”, “scratch”, “collision with ,mobile things” , “breaking” increase due to heat exposure.[14] Although it has not been investigated how heat exposure may exacerbate the risk of physical injuries. However, studies revealed that injuries may be a minor or secondary result of heat-related disease or it may be due to physiological, psychological, personal and organizational (related to work) factors. To understand physiological factors, it is important to know how the body retains its thermal balance and how it reacts in hot environments. Human as a warm-blooded creature has an internal temperature between 5.36°C to 37°C and 32°C skin temperature. Body temperature may change daily or hourly, but these changes are not more than one centigrade degree, as the human body can regulate body internal temperature through two nervous and hormone control systems.[61-63] Hypothalamus in the brain regulates body internal temperature through radiation, transmission, guidance and sweat evaporation. When the body temperature regulation system is not able to tolerate environment temperature, serious dangers threaten humans' health and body temperature reaches above 39°C and extreme heatstroke may happen. The human body supplies its thermal energy through the consumption of daily meals. Also, environmental resources including high temperature, high relative moisture, absence of airflow, sun radiation and hot sources and surfaces influence energy production in the body.[13, 64] Physical heat exposure injuries on the human body are compatible with human’s ability to regulate internal temperature as blood circulation in the skin has the most effect on controlling body internal temperature and if it doesn't work well, body internal temperature increases and

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makes human heat exposure effects. And due to the reduction in blood circulation amount in the brain, the human feels dizziness and unconsciousness.[61] In higher temperatures, due to more sweating a large amount of water, salt, and free electrolytes remove from the body which leads to heat cramps due to dehydration and electrolyte imbalance.[65] These effects may influence body temperature regulation systems and create heat exposure symptoms in the body. Symptoms progress may influence workers' ability and increase job accidents;[17] which is due to a reduction in cognitive performance and perceptual-movement skills in the human brain. [66-69] Physiological effects which workers experience in hot environments may cognitively increase hazardous behaviors in work environments which eventually increase job injuries and accidents. Humans' attention and concentration are reduced in hot environments and lead to unsafe behaviors. Surprisingly, cognitive reactions reduction begins with a slight increase in body temperature and reduction inability to do tasks and performance in individuals before the incidence of a heat-related disease is predictable.[30] Also, organizational and personal behavioral factors may lead to injuries. These are including not using personal safety equipment due to heat and moistening of the palms, reduction in hand grasp and eyesight problems due to sweating. Other influential factors maybe insufficiency in protective covering and absence of supervision and education in prevention from heat stress.[8, 11, 13, 16] Although there are reports about heat exposure job injuries, obvious mechanisms are not still determined which necessitate more studies in the future. Study results show that cognitive and physical performance may be influenced by extreme heat. There is a probability in the occurrence of unsafe behaviors which leads to injuries and accidents. Activities like judgment, concentration, coordination, resistance, power, eyesight, and convenience are under the influence of physiological changes due to heat and body dehydration. [70, 71] Many other studies have tried to predict another list of factors which may someone be more exposed to environmental dangers. These factors include palms moistening, steamed safety goggles, random contact with hot surfaces, physical activities, absence of practice and skill, unsuitable heat regulation mechanism due to age increase, using unsuitable personal safety devices, work environment stresses, weak dehydration behaviors.[13, 41, 48] 20% of studies conducted utilizing WBGT Index which demonstrates Wet Bulb Globe Temperature (WBGT) to evaluate work environment heat pressure, this index has been selected as the main representative in establishment of legal threshold amounts due to easiness in measurement method and also close relationship with corrected effective temperature from the experts' national association of America industrial health. Health National Studies and Occupational Safety Center and International Standard Organization (ISO) have suggested it as the standard index; Wet Bulb Globe Temperature (WBGT) is so simple and measures the least atmospheric factors. This index is based on measuring natural wet and dry temperature. [61] Less exposure to heat by proper performing of engineering and management strategies may reduce the number of accidents and injuries in work environments. Several instructions and recommendations have introduced by different health and occupational groups and governmental officials for workers.[41] However, there is less focus on prevention from heat exposure injuries in medium heat work environments rather than extreme heat ones. Therefore, changes in safety policies and occupational health and educational programming based on evidence are necessary for workers and supervisors. Since articles investigation has been conducted in several databases and utilizing some related keywords, though there may be some other studies which persuaded the reverse relationship between heat and job injuries and accidents not included into the present study, however researchers have tried to study the whole articles which have been conducted in Iran and other foreign countries. It is recommended to conduct studies considering job type, level of physical activity (light, medium, heavy) and individuals' features to determine the exact effect of heat on work environment injuries and accidents. Especially, according to the predictions about increasing Earth's temperature between 1 to 5 centigrade degrees until 2070 (depending on greenhouse gases) the risk of heat exposure injuries may increase for those who work outdoors. Also, heat delayed effects on humans have to be studied because injuries may potentially don't happen on the same day of heat exposure. Also, it is recommended to conduct studies about the economic effects of heat exposure injuries and accidents and their health costs.

Conclusion

The present study represents evidence based on hot environments dangers and direct and indirect factors in job injuries and accidents that necessities purposeful interventions and working policies along with preventive

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strategies. Results study shows that there is a strong relationship between temperature in the open air and an increase in the risk of work environment injuries and accidents which differ based on employees' features (such as age, gender, occupation, and industry). However, dominant mechanisms on these injuries are having not been determined yet. According to global warming which leads to air temperature increase and creation of hot days, the number of accidents, job injuries and efficiency harms are expected to be increased and its effect may be reduced through compatibility with specific behaviors and controlling work among industries and workers with vulnerable occupations. More studies are needed to determine specific injuries and incidence of injuries in hot work environments. Policymakers and employers have to be more aware of heat exposure injuries and accidents and proper educational resources have to be prepared to prevent such injuries.

References

1. Kjellstrom T, Kovats RS, Lloyd SJ, Holt T, Tol RS. The direct impact of climate change on regional labor productivity. Archives of Environmental & Occupational Health. 2009;64(4):217-27.
2. Nassiri P, Monazzam MR, Golbabaei F, Dehghan SF, Rafieepour A, Mortezapour AR, et al. Application of Universal Thermal Climate Index (UTCI) for assessment of occupational heat stress in open-pit mines. Industrial Health. 2017;55(5):437-43.
3. Vatani J, Golbabaei F, Dehghan SF, Yousefi A. Applicability of Universal Thermal Climate Index (UTCI) in occupational heat stress assessment: a case study in brick industries. Industrial health. 2015.
4. Lundgren K, Kuklane K, Gao C, Holmer I. Effects of heat stress on working populations when facing climate change. Industrial health. 2013;51(1):3-15.
5. Heidari H, Golbabaei F, Shamsipour A, Forushani AR, Gaeini A. Outdoor occupational environments and heat stress in IRAN. Environmental health science and engineering. 2015;13(1):48.
6. Hajizadeh R, Golbabaei F, Farhang Dehghan S, Beheshti MH, Jafari SM, Taheri F. Validating the heat stress indices for using in heavy work activities in hot and dry climates. Research in health sciences. 2016;16(2):90-5.
7. Mazlomi A, Golbabaei F, Farhang Dehghan S, Abbasinia M, Mahmoud Khani S, Ansari M, et al. The influence of occupational heat exposure on cognitive performance and blood level of stress hormones: A field study report. International journal of occupational safety and ergonomics. 2017;23(3):431-9.
8. Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. Agromedicine. 2010;15(3):200-15.
9. Hunt A, Parker A, Stewart I. Symptoms of heat illness in surface mine workers. International archives of occupational and environmental health. 2013;86(5):519-27.
10. Dutta P, Rajiva A, Andhare D, Azhar GS, Tiwari A, Sheffield P, et al. Perceived heat stress and health effects on construction workers. Indian journal of occupational and environmental medicine. 2015;19(3):151-8.
11. Bethel J, Harger R. Heat-related illness among Oregon farmworkers. International journal of environmental research and public health. 2014;11(9):9273-85.
12. Kearney GD, Hu H, Xu X, Hall MB, Balanay JAG. Estimating the prevalence of heat-related symptoms and sun safety–related behavior among Latino farmworkers in Eastern North Carolina. Agromedicine. 2016;21(1):15-23.
13. Spector JT, Krenz J, Blank KN. Risk factors for heat-related illness in Washington crop workers. Agromedicine. 2015;20(3):349-59.
14. Tawatsupa B, Yiengprugsawan V, Kjellstrom T, Berecki-Gisolf J, Seubsman S-A, Sleigh A. Association between heat stress and occupational injury among Thai workers: findings of the Thai Cohort Study. Industrial health. 2013;51(1):34-46.
15. Morabito M, Cecchi L, Crisci A, Modesti PA, Orlandini S. Relationship between work-related accidents and hot weather conditions in Tuscany (central Italy). Industrial health. 2006;44(3):458-64.
16. Harduar Morano L, Bunn T, Lackovic M, Lavender A, Dang G, Chalmers J, et al. Occupational heat-related illness emergency department visits and inpatient hospitalizations in the southeast region, 2007–2011. American journal of industrial medicine. 2015;58(10):1114-25.
17. Harduar Morano L, Watkins S, Kintziger K. A comprehensive evaluation of the burden of heat-related illness and death within the Florida population. International journal of environmental research and public health. 2016;13(6):551.
18. Basu R. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environmental health. 2009;8(1):40.
19. Fogleman M, Fakhrzadeh L, Bernard TE. The relationship between outdoor thermal conditions and acute injury in an aluminum smelter. International journal of industrial ergonomics. 2005;35(1):47-55.
20. Kjellstrom T, Gabrysch S, Lemke B, Dear K. The 'Hothaps' programme for assessing climate change impacts on occupational health and productivity: an invitation to carry out field studies. Global health action. 2009;2(s2):2082.
21. Schulte PA, Chun H. Climate change and occupational safety and health: establishing a preliminary framework. Occupational and environmental hygiene. 2009;6(9):542-54.
22. Hajizadeh R, Golbabaei F, Monazzam MR, Farhang-Dehghan S, Ezadi-Navan E. Productivity loss from occupational exposure to heat stress: A case study in Brick Workshops/Qom-Iran. International journal of occupational hygiene. 2014;6(3):143-8.
23. Vangelova K, Deyanov C, Ivanova M. Dyslipidemia in industrial workers in hot environments. Central European journal of public health. 2006;14(1).
24. Tawatsupa B, Lim L-Y, Kjellstrom T, Seubsman S-a, Sleigh A, Team TCS. The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers. Global health action. 2010;3(1):5034.
25. Tawatsupa B, Lim LL, Kjellstrom T, Seubsman S-a, Sleigh A, Team TCS. Association between occupational heat stress and kidney disease among 37 816 workers in the Thai Cohort Study (TCS). Epidemiology. 2012;22(3):251-60.
26. Luo H, Turner LR, Hurst C, Mai H, Zhang Y, Tong S. Exposure to

[Downloaded from aoh.ssu.ac.ir on 2024-10-12]

[DOI: 10.18502/aoh.v4i2.2707]

ambient heat and urolithiasis among outdoor workers in Guangzhou, China. Science of the total environment. 2014;472:1130-6.
27. Australia SW. Occupational health and safety statistics report-number of cases. 2011.
28. Hübler M, Klepper G, Peterson S. Costs of climate change: the effects of rising temperatures on health and productivity in Germany. Ecological economics. 2008;68(1-2):381-93.
29. Hocking C, Silberstein RB, Lau WM, Stough C, Roberts W. Evaluation of cognitive performance in the heat by functional brain imaging and psychometric testing. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology. 2001;128(4):719-34.
30. Hancock PA, Vasmatzidis I. Effects of heat stress on cognitive performance: the current state of knowledge. International journal of hyperthermia. 2003;19(3):355-72.
31. Stubblefield ZM, Cleary MA, Garvey SE, Eberman LE. Effects of active hyperthermia on cognitive performance. 2013.
32. Knapik JJ, Canham-Chervak M, Hauret K, Laurin MJ, Hoedebecke E, Craig S, et al. Seasonal variations in injury rates during US Army Basic Combat Training. Annals of occupational hygiene. 2002;46(1):15-23.
33. Bhattacherjee A, Bertrand J-P, Meyer J-P, Benamghar L, SIERRA CO, Michaely J-P, et al. Relationships of physical job tasks and living conditions with occupational injuries in coal miners. Industrial health. 2007;45(2):352-8.
34. Chau N, Bourgkard E, Bhattacherjee A, Ravaud JF, Choquet M, Mur JM, et al. Associations of job, living conditions and lifestyle with occupational injury in working population: a population-based study. International archives of occupational and environmental health. 2008;81(4):379-89.
35. Adam-Poupart A, Smargiassi A, Busque MA, Duguay P, Fournier M, Zayed J, et al. Effect of summer outdoor temperatures on work-related injuries in Quebec (Canada). Occupational Environmental Medicine. 2015;72(5):338-45.
36. Xiang J, Hansen A, Pisaniello D, Bi P. Workers' perceptions of climate change related extreme heat exposure in South Australia: A cross-sectional survey. BMC public health. 2016;16(1):549.
37. Golbabaei F, Hamerezae M, Fathi A, Dibakhosravi A. Studying the effectiveness of re-hydration on productivity in a sugar beet workers among farmers in West Azarbaijan city. Health and safety at work. 2014;4(3):49-58. [Persian]
38. NAG PK, NAG A. Shiftwork in the hot environment. Human ergology. 2001;30(1-2):161-6.
39. Biswas MJ, Koparkar AR, Joshi MP, Hajare ST, Kasturwar NB. A study of morbidity pattern among iron and steel workers from an industry in central India. Indian journal of occupational and environmental medicine. 2014;18(3):122-8.
40. Spector JT, Bonauto DK, Sheppard L, Busch-Isaksen T, Calkins M, Adams D, et al. A case-crossover study of heat exposure and injury risk in outdoor agricultural workers. PLoS one. 2016;11(10):e0164498.
41. McInnes JA, Akram M, MacFarlane EM, Keegel T, Sim MR, Smith P. Association between high ambient temperature and acute work-related injury: a case-crossover analysis using workers' compensation claims data. Scandinavian journal of work, environment & health. 2017;43(1):86-94.
42. Golbabaei F, Mazloumi A, Mamhood Khani S, Kazemi Z, Hosseini M, Abbasinia M, et al. The effects of heat stress on selective attention and reaction time among workers of a hot industry: application of computerized version of stroop test. Health and safety at work. 2015;5(1):1-10. [Persian]
43. Rameezdeen R, Elmualim A. The impact of heat waves on occurrence and severity of construction accidents. International journal of environmental research and public health. 2017;14(1):70.
44. Sahu S, Sett M, Kjellstrom T. Heat exposure, cardiovascular stress and work productivity in rice harvesters in India: implications for a climate change future. Industrial health. 2013;51(4):424-31.
45. Jain A, Aswar N, Kale K, Doibale M. Work related injuries an d some associated risk factors among workers in iron and steel industry. Scholars journal of applied medical sciences. 2015;3(2):901-5.
46. Garzon-Villalba XP, Mbah A, Wu Y, Hiles M, Moore H, Schwartz SW, et al. Exertional heat illness and acute injury related to ambient wet bulb globe temperature. American journal of industrial medicine. 2016;59(12):1169-76.
47. Xiang J, Bi P, Pisaniello D, Hansen A, Sullivan T. Association between high temperature and work-related injuries in Adelaide, South Australia, 2001–2010. Occupational Environmental Medicine. 2014;71(4):246-52.
48. Xiang J, Bi P, Pisaniello D, Hansen A. The impact of heatwaves on workers' health and safety in Adelaide, South Australia. Environmental research. 2014;133:90-5.
49. Singh S, Hanna EG, Kjellstrom T. Working in Australia's heat: Health promotion concerns for health and productivity. Health promotion international. 2013;30(2):239-50.
50. Monazzam Esmaielpour MR, Golbabaei F, Khodayari F, Aazam K. Survey of the productivity loss due to heat stress in different tasks of farmers in Darreh Shahr city. Health and Safety at Work. 2015;5(3):63-74. [Persian]
51. Mobasheri-Demneh M, Dehghan H, Karimi A, Khalili-Gorji H, Zeinoddini M, Pourbaferani AR, et al. Evaluation of Environmental, Physiological, and Perceptual Heat Indices among Underground Mine Workers. Health System Research. 2018;13(4):393-8.[Persian]
52. Mathee A, Oba J, Rose A. Climate change impacts on working people (the HOTHAPS initiative): findings of the South African pilot study. Global health action. 2010;3(1):5612.
53. Langkulsen U, Vichit-Vadakan N, Taptagaporn S. Health impact of climate change on occupational health and productivity in Thailand. Global health action. 2010;3(s3):5607.
54. Hajizadeh R, Farhang Dehghan S, Mehri A, Jafari SM, Golbabaei F, Haghighat jou H. Effect of heat stress on productivity loss of outdoor workers: a case study in a hot and dry climate. Health. 2018;9(3):302-13. [Persian]
55. Brake D, Bates GP. Fluid losses and hydration status of industrial workers under thermal stress working extended shifts. Occupational and environmental medicine. 2003;60(2):90-6.
56. Page L, Sheppard S. Heat Stress: the impact of ambient temperature on occupational injuries in the US. 2016.
57. Hiles MH. Relationships of heat stress levels to heat-related disorders and acute injury during deepwater horizon cleanup operations. 2012.

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[DOI: 10.18502/aoh.v4i2.2707]

58. Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. International journal of biometeorology. 2014;58(8):1779-88.
59. Aswar N. Work related injuries and some associated risk factors among workers in iron and steel industry. 2015.
60. Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. Industrial health. 2013;52(2014):91-101.
61. Parsons K. Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance: CRC press; 2014.
62. Sherwood L. Human physiology: from cells to systems: Cengage learning; 2015.
63. Kenney WL, Wilmore JH, Costill DL. Physiology of sport and exercise: Human kinetics; 2015.
64. Sawka MN, Leon LR, Montain SJ, Sonna LA. Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. Comprehensive Physiology. 2011;1(4):1883-928.
65. Powers SK, Howley ET. Exercise physiology: Theory and application to fitness and performance: McGraw-Hill New York, NY; 2007.
66. Jay O, Kenny GP. Heat exposure in the Canadian workplace. American journal of industrial medicine. 2010;53(8):842-53.
67. Ganio MS, Armstrong LE, Casa DJ, McDermott BP, Lee EC, Yamamoto LM, et al. Mild dehydration impairs cognitive performance and mood of men. British journal of nutrition. 2011;106(10):1535-43.
68. Zemková E, Hamar D. Physiological mechanisms of post-exercise balance impairment. Sports Medicine. 2014;44(4):437-48.
69. DiStefano LJ, Casa DJ, Vansumeren MM, Karslo RM, Huggins RA, Demartini JK, et al. Hypohydration and hyperthermia impair neuromuscular control after exercise. Medicine and science in sports and exercise. 2013;45(6):1166-73.
70. Kenefick RW, Sawka MN. Hydration at the work site. The american college of nutrition. 2007;26(sup5):597S-603S.
71. Murray B. Hydration and physical performance. The american college of nutrition. 2007;26(sup5):542S-8S.

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