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REVIEW ARTICLE

Review of Occupational Heat Stress over the Past 50 Years in Iran

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ABSTRACT

Thermal stress is a well-recognized health hazard in the workplace. In addition to the health deficits, working in the heat can affect significantly on the productivity of some industries located in rough environments. The current indices used to evaluate the environment are either flawed or difficult to implement. The focus of this review is upon heat stress indices used in Iran to evaluate occupational thermal stress. In this systematic review, the research team searched both bibliographic, citation databases for related heat stress articles in Iran over the past 50 yr. Different search engines were used, and the search strategy was the same in the all searched databases. Twenty papers reviewed through bibliographic database and 30 papers reviewed through citation database. Then the total identified was 50 papers and thesis. Fifteen duplicate papers were removed and finally, 35 were included. In particular, there is a review about the wet-bulb globe temperature (WBGT) index, and an overview of other heat stress indices may be undertaken. These principles and methods are combined to illustrate how one may evaluate the risk of heat illness. Three general areas of research are briefly reviewed: climate change, clothing effects, and physiological parameters. These topics are compared with the published researches from other countries. Over the years in Iran, too much emphasis has been placed on the academic accuracy of an index at the expense of practicability. In addition, the studies in Iran showed few detailed researches with a target of preventive measures and intervention to mitigate adverse effects and there is no strong focus on sustainable development.

KEYWORDS: *Heat stress, WBGT, Occupational health, Indices*

INTRODUCTION

Workers are often exposed to severe environmental heat stress especially in hot and dry areas and seasons, which may deteriorate work efficiency and productivity and may even threaten survival [1]. Therefore, body-core temperature should maintain in low ranges because its supposed physiological heat strain can effect on total heat stress [2].

Thermal stress is assessed both for scientific research and for practical ends [3]. Over the past half century, the increasing demand for such standards and guidelines has focused attention on indices of thermal stress, while the assessment of its component factors has been largely neglected and is now believed to be difficult, expensive, and time-consuming.

Heat stress is readily associated with high environmental temperatures and humidities. These conditions frequently appear in primary metals, ceramic, food processing, electric power, and construction industries [4].

Principal sources of guidance in the evaluation of heat stress were National Institute for Occupational Safety and Health [4], the American Conference of Governmental Industrial Hygienists [5], and the International Organization for Standardization [6].

A common element in the evaluation process proposed by these organizations is the use of the WBGT (wet bulb globe temperature) to characterize the environment.

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This paper is a review on assessing occupational heat stress in Iran over the past 50 yr. The main objective of the review was to prevent duplicating done researches and concentrate on the gaps in the issue more.

MATERIALS AND METHODS

In this systematic review, the research team searched both bibliographic and citation databases for related heat stress articles in Iran between 1960 to 2016 years. The search engines were PubMed, Elsevier, Scopus and the citation databases were Web of science, Wiley and Springer, Magiran, SID, and all Iranian database in the subject. The search strategy was the same in the all searched databases. The terms used for searching were heat stress, thermal stress, heat indices and specific author name.

After the first searching, the duplicate articles were removed. Then the articles and thesis were screened in terms of study eligibility, inclusion criteria and extracted data related to the research topic. Papers included were published in peer-reviewed English and Persian language journals over the past 50 yr and cited ineligible databases. All correspond authors of selected articles have the academic or organizational affiliation to heat stress issues.

Then relevant papers were reviewed in detail, with issues discussed in each paper compared to verify accuracy and consistency of opinions. Differences in the conclusions of the papers were considered and critically analyzed in order to report the most important concerns about heat stress status in Iran. Twenty papers reviewed through bibliographic database and 30 papers reviewed through citation database. Then the total identified was 50 papers and thesis. Fifteen duplicate papers were removed and finally, 35 were included.

RESULTS

The search strategy and application of the inclusion criteria given heat stress indices concepts published over the past 50 yr. Based on literature review and separating different heat stress assessment procedures into 4 main categories as occupational heat stress, heat stress in exercise, heat stress adaptation and others (Fig.1). The review of 20 papers and thesis showed that they were categorized in occupational heat stress, which was measuring and comparing different heat stress indices. Two papers related to heat stress in exercise, two papers described heat stress adaptation and the rest debated more about concepts and theoretical approaches to the heat stress assessment. Table 1 summarizes papers published in academic journals.

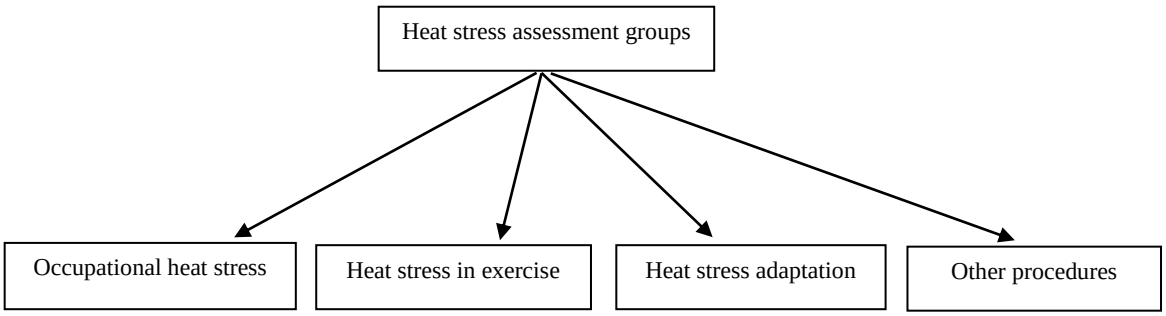

Fig.1. Categorization of heat stress assessment procedures

These latest studies indicate several important points such as; physical stresses of working environment can lead to changes in physiology of human body. Thus, variations in hormone level in its consequences in hot environment should be considered in occupational hygiene [7]. On the other hand, in hot/dry conditions of melting and casting processes, despite moderate correlation between WBGT index with ear canal temperature and PSI index, work-rest cycles of WBGT index is not applicable for many of the workstations. Therefore, heat stress evaluation based on physiological variables probably has higher validity and is more appropriate [8]. In addition, 100% cotton clothing ensemble during low-workload activities and 30.2% cotton-69.8% polyester clothing ensemble during moderate-workload activities is used for Iranian workers to maintain the cardiac and physiological strains as low as possible [9].

Overall, 95% of heat stress assessment in the understudying country, Iran, comes back to heat stress indices measurements that evaluate hot environments and help us to suggest an appropriate control method (Table 1). The heat indices that most of the review articles used were Wet Bulb Globe Temperature (WBGT) index (85%), Heat Stress Index (HSI) (7%), Physiological Strain Index based on Heart Rate (PSIHR) (4%), Predicted Four-Hour Sweat Rate (P4SR) (2%), Required Sweat Rate (SWreq) (1%) and Discomfort Index (DI) (1%).

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Table 1. Overview of latest studies in heat stress

Article title	Publication Year	Authors	Groups	Study target
The influence of occupational heat exposure on cognitive performance and blood level of stress hormones: A field study report [7]	2016	Mazloumi A, Golbabaei F, et al	Occupational heat stress	The effect of heat on biomarkers such blood level
Validating the heat stress indices for using in heavy work activities in hot and dry climates [29]	2016	Hajizadeh R, Golbabaei F, et al	Occupational adaptation	Assess the precision and validity of some heat stress indices and select the optimum index for using in heavy work activities in hot and dry climates
Heat stress assessment in outdoor workplaces of a hot arid climate based on meteorological data: A case study in Qom [30]	2015	Hajizadeh R, Farhang S, et al	Occupational heat stress	Assess the occupational heat stress using WBGT and ESI indexes in outdoor workplaces of the Qom province as a hot-arid climate
Effects of heat stress on selective attention and reaction time workers in a hot industry: application of PC Stroop test [22]	2015	Golbabaei.F, Mazloomi.A, Mahmudkhani.S, et.al	Occupational heat stress	The effect of heat on selective attention and reaction time of workers before and during the work of the Stroop test
The Effect of Fabric Type of Common Iranian Working Clothes on the Induced Cardiac and Physiological Strain Under Heat Stress [9]	2015	Parvari R, Aghaei H, et al	Occupational heat stress	Comparing the effect of fabric type of working clothes on heat strain responses in different levels of physical workload and under different kinds of weather conditions
Heat stress and its impact on the workers' cortisol concentration: A case study in a metal melding industry [31]	2014	Ansari M, Mazloumi A, et al	Occupational heat stress	Investigating the effect of heat stress on the cortisol concentration of workers in one of the melting industries
Evaluating effects of heat stress on cognitive function among workers in a hot industry [32]	2014	Mazloumi A, Golbabaei F, Mahmood Khani S, et al	Occupational adaptation	Evaluating the impact of thermal stress on cognitive function among workers in a hot industry
Productivity loss from occupational exposure to heat stress: A case study in Brick Workshops/Qom-Iran [33]	2014	Hajizadeh R, Golbabaei F, et al	Occupational heat stress	Evaluating outdoor workplaces in hot-dry climates because it can disrupt the physical or mental functions and effect negatively on human performance
Heat Stress and Physical Capacity [19]	2014	Golbabaei.F, Zakerian.A, et.al	Heat stress in exercise	Determine heat stress effect on physical capacity of semi-professional footballers in Iran
The Assessment of Heat Stress and Heat Strain in Pardis Petrochemical Complex [34]	2013	Golbabaei F, Monazam M, Hemmatjoo R, et al	Occupational adaptation	Comparing WBGT index at acclimated and unacclimated people to permissible threshold limit value and study the differences between physiological parameters at them
Studying heat stress in small work places in Qom [23]	2013	Hajizadeh.R, Beheshti.M, et.al	Occupational heat stress	Evaluate thermal stress according to WBGT index & relationship between WBGT & physiologic indices
The relationship between observational perceptual heat strain evaluation method and environmental/physiological indices in warm workplace [35]	2013	Dehghan H, Habibi E, et al	Occupational heat stress	Determine validation of an observational – perceptual method as heat strain Score Index (HSSI) in warm conditions

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Validation of a questionnaire for heat strain evaluation in women workers [36]	2013	Dehghan H, Habibi E, et al	Occupational heat stress	Determining the validity of a questionnaire method for assessing women's heat strain in workplaces
Cardiac strain between normal weight and overweight workers in hot/humid weather in the Persian Gulf [37]	2013	Dehghan H, Mortazavi B, et al	Occupational heat stress	Comparing cardiac strain among overweight and normal-weight workers in hot, humid conditions in the south of Iran
The evaluation of heat stress through monitoring environmental factors and physiological responses in melting and casting industries workers [8]	2012	Dehghan H, Mortazavi B, et al	Occupational adaptation	Comparing results of heat strain evaluation by monitoring environmental factors and physiological responses
Combination of wet bulb globe temperature and heart rate in hot climatic conditions: The practical guidance for a better estimation of the heat strain [38]	2012	Dehghan H, Mortazavi B, et al	Occupational heat stress	Evaluating the combined application of wet bulb globe temperature (WBGT) and physiological strain indices based on heart rate (PSI_{HR}) for the estimation of heat strain, in hot climatic conditions
Thermal stress on the furnace workers in a forging industry in summer [39]	2012	Azari.Gh, Mofidi.A, et.al	Occupational heat stress	Evaluate thermal stress in the situation according to WBGT index
Combined application of WBGT & PSI_{HR} indices in hot weather [13]	2012	Dehghan.H, Mortazavi.B, et.al	Occupational adaptation	Studying a good tool to assess heat strain in hot weather
Evaluation of wet bulb globe temperature index for estimation of heat strain in hot/humid conditions in the Persian Gulf [40]	2012	Dehghan H, Mortazavi B, et al	Occupational heat stress	Evaluating the performance of wet bulb globe temperature (WBGT) Index for estimation of heat strain in hot/humid conditions by the use of Physiological Strain Index (PSI) as the gold standard
Construct validation of a heat strain score index with structural equation modeling [41]	2011	Dehghan H, Mortazavi B, et al	Occupational heat stress	Developing and validate the "Heat Strain Score Index (HSSI) in Iran's climatic conditions
Comparing the heat stress (WBGT, DI, SW) indices [12]	2011	Golbabaei.F, Monazam.M, Hemmatjoo.R, et.al	Occupational heat stress	Develop an optimal index based on physiological parameters in a petrochemical industry
Determine effect of cloth type on PSI index [18]	2011	Dehghan.H, Parvari.R, et.al	Occupational adaptation	Determine the proper cloth type in hot environment
Design and evaluation of validity and reliability of a questionnaire method for pre-assessment of heat stress in workplace [24]	2011	Dehghan.H, Mortazavi.B, et.al	Occupational heat stress	Questionnaire method for pre-assessment of heat stress is a valid method or not?
Heat stress control in melting platform at one of smelteries in Tehran [42]	2011	HajiAzimi.E, Khavanin.A, et.al	Occupational heat stress	Applying a proper control method for decreasing radiant heat melts
Using structural equation modeling to validate a heat strain screening method [43]	2010	Dehghan.H, Mortazavi.B, et.al	Occupational heat stress	Is heat strain score index a valid method or not?

DISCUSSION

The majority of heat stress studies in Iran tended to assess hot environments, using heat stress indices. Researchers used different heat stress indices to determine heat stress levels in various duties. Then they compared results with each other to identify which indice (s) has (have) the capacity to use for next investigations.

The studies in Iran carried out in factories such as metallurgy, foundry, making tile, petrochemical industries and bakery as a small workshop. Besides assessing hot occupational situation, in the studies some factors relating to heat stress measured and evaluated with different heat stress indices. The factors were such as

climate change, clothing effects, and physiological parameters. The evaluations are done by three well-established indices namely HSI, WBGT, and the P4SR. These three indices are useful for comparing measurements about physiological and subjective responses to heat. They predict likely sweat rates and hence water requirements from P4SR and assess the severity of the environment from a consensus of all three indices. Although any prediction of the likelihood of adverse effects should be interpreted, given the known limitations of all heat stress indices and the fallibility of their predictions in the light of the workshop's records that show whether adverse effects have in fact been occurring [10].

HIS and WBGT at bakeries were compared [11]. HSI was weaker than WBGT and it had more deviation. Besides, the usage of WBGT in smelters and foundries for evaluating heat stress [12-13]. The same result was obtained in study on smelters [14].

DI, WBGT and SWreq comparing in a research showed WBGT index has the most correlation coefficient with heart rate and it is an optimum index [15]. In addition, WBGT alone is the poor index to assess heat strain in hot weathers but combined application of WBGT & PSIHR indices in hot weather is a useful tool [16-17].

Climatic change can make hot days hotter. People who are carrying out physically demanding jobs are particularly affected by ambient heat as their muscle movements create waste heat inside the body, which cannot easily be transferred to the surrounding air when the air temperature is higher than the body temperature [18]. Iran geographically is a hot and dry country. Field studies in Iran are currently implemented in Kashan, Hamedan, Qom, Bushehr and Arak, Iran. The findings show the importance of workplace heat in creating health risks and reducing labour productivity [19-20]. Lundgren declared in all countries analyses more detailed of geographic, climatic variations, and susceptible professions and workplaces are needed in order to quantify the effect on health, work capacity and productivity [21].

In hot environments, sweating is the most important heat loss mechanism for people who are working, training or doing leisure activities [22]. The other aspect for hot environments is to measure physiologic parameters such as ear temperature, oral temperature, dehydration, urine density, heart rate and so on. The appropriate material of clothing for decreasing heat strain in hot and humid environment for light activity, moderate activity, and hot & dry environment is respectively 100% cotton, and 30% cotton- 70% polyester [23]. In addition, ear temperature has a strong correlation with WBGT and urine density is a good biomarker to determine dehydration status in hot professions [24-25]. It was adjustable conclusion. Metabolic level and clothing do affect critical conditions and heat strain. Increasing the metabolic rate will lower the critical conditions but increase the physiological strain reflected in HR and PSI [26-27].

Despite some limitation, WBGT achieved the most attention in hot environment assessments. In this regard, Moran developed a new environmental stress index (ESI) based on different parameters relating to heat stress. Therefore, a new heat stress index was developed based on done measurements in hot/wet, hot/dry, and extremely hot/dry climate for 60 d:

Equation 1:

$$ESI = 0.63T_a - 0.03RH + 0.002SR + 0.0054(T_a.RH) - 0.073(0.1 + SR)^{-1}$$

Where:
T_a: ambient temperature (C),
RH: relative humidity (%),
SR: solar radiation (W. m^{-1}).

ESI can be a very practical alternative for WBGT because the correlation coefficient between them is so high (R_2>0.981) [28].

Indices of heat stress, although convenient, are always complementary to measurements of the four primary quantities- air temperature, mean radiant temperature, water vapour pressure, and air velocity- and to records of the workers' clothing and activity. Indices can never substitute for these [10].

In all countries, analyses more detailed of geographic, climatic variations and susceptible professions and workplaces are needed in order to quantify the effect on health, work capacity and productivity. Further research should identify methods and models for prediction of occupational heat stress from a global warming point of view. Research must be also focused on preventive measures and intervention to mitigate adverse effects with a strong focus on sustainable development but the studies in Iran showed few detailed researches in the case.

CONCLUSION

Over the past 50 yrs in Iran, the increasing demand for such standards and guidelines has focused attention on indices of thermal stress and it can be quickly and comprehensively assessed by a single observer using simple and inexpensive

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instruments. Over the years in Iran, too much emphasis has been placed on the academic accuracy of an index at the expense of practicability. In reality, the prevailing conditions in workplaces are not uniform, as they are under laboratory conditions. In such casework is performed under varying degrees of physical workload, heat stress, and work periods. Other confining factors may be different types of clothing, gender, degree of acclimatization age, etc. This systematic review showed these procedures, to be accurate and informative in industry consultancies and research projects over the past 50 yr. Therefore, in the writers' view, the use of a "direct index" together with appropriate, simple, and practical guidelines accounting for work intensity and clothing is the preferred way of expressing thermal stress.

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