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Lifestyle Factors Influencing Heat Stress Response: A Review

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ABSTRACT: Exposure to hot thermal environment is present in a great number of indoor and outdoor working activities, posing a risk of illnesses and with aggravation in some cases lead to death. The aim of this review was to investigate on lifestyle factors influencing human heat stress response. The review was conducted using the PRISMA methodology. For searching purpose, 31 keywords and expressions were selected, screening 251 electronic databases through the Brazilian CAPES searching system. Articles were included if published on English, Portuguese, Spanish, Italian or Croatian language. No publication date limit was added. The identification process resulted with 1142 articles. After applying the exclusion and inclusion criteria's it resulted with 18 articles included in this review. In this review, 10 additional factors were analyzed. It was concluded that apart from the basic factors, future studies conducting experiments on human heat exposure, should consider participant's lifestyle factors during the selection process.

KEYWORDS: hot thermal environment; high temperatures; thermoregulation; human factors

1 INTRODUCTION

Exposure to hot thermal environment is a significant risk factor present indoor in all seasons (foundries, steel mills, bakeries, smelters, glass factories, and furnaces, and highly humid laundries, restaurant kitchens, and canneries) and outdoor during the summer season (in occupations such as road repair, marine, army, agriculture, forestry, mining, factory work, construction work, among summer sport athletic disciplines and related occupations) (Canadian Centre for Occupational Health & Safety 2016). Outdoor exposure to hot is of particular interest for regions near the Equator where the temperatures are high year round with exceptions of high mountains. Further on, overall global temperatures show a fast increasing trend during the past decades(Carlowicz 2017).

Further on, heat exposure can lead to a number of illnesses: heat edema, heat rashes, heat cramps, heat exhaustion, heat syncope and heat stroke; and with aggravation in some cases lead to death (Canadian Centre for Occupational Health & Safety 2016; Jacklitsch et al. 2016). With increased attention on climate change during recent years, public interest increased attention on the effects of heat exposure (Kjellstrom 2009). Therefore, understanding that heat exposure affects a great population and understanding the level of risk posed by heat exposure, it is important to comprehend factors important for worker's heat stress evaluation.

Past studies concluded that there are six basic factors to take in consideration in heat exposure: air temperature, radiant temperature, relative humidity, air movement, metabolic heat generated by human activity and clothing worn by a person (K.C.Parsons 2003). However, while many present studies considered the mentioned basic factors, there is a need to further on the research, adding more factors in order to get consistent and comparable results. In order to do so, there is a need to investigate on additional factors influencing human response on heat exposure, study the importance of each one of them and give suggestions for improving future studies.

The aim of this review was to investigate on lifestyle factors influencing human heat stress response: smoking cigarettes, alcohol, coffee, tea, water and food intake, spicy food intake, sleeping hours, human physical condition and body fat. Further on, encountered variables were studied in order to evaluate the importance of each one of them.

2 METHODOLOGY

2.1 Searching strategy

The academic and clinic PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses was used in creating and modeling this article (Liberati et al. 2009). References were managed using the Mendeley 1.15.3. For searching purposes, the following 31 keywords/expressions were defined: "hot thermal environment*", "hot temperature*" AND exposure*", "hot exposure*", "metab* AND exposure* AND hot", "disease* AND exposure* AND hot", "illness* AND exposure* AND hot", "injur* AND exposure* AND hot", "accident* AND exposure* AND hot", "death AND exposure* AND hot", "clothing AND hot AND exposure*", "physi* AND exposure* AND hot", "psycholog* AND exposure* AND hot", "productivity AND human AND hot", "performance* AND human AND hot", "heat stress AND work*", "hot thermal condition*". Additional 15 keywords and expressions were created by replacing the word "hot" with word "warm" in all previously mentioned keywords and expressions. Using selected keywords and expressions, the articles were searched by title and subject in 251 electronic databases through the CAPES (Brazilian Coordination of Improvement of Higher Level Personnel) searching system (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior 2017). When articles were encountered, first exclusion criteria's were applied, afterward the articles were fully downloaded and screened, and inclusion criteria's were applied.

2.2 Exclusion and inclusion criteria's

There was no publishing year limit. Articles were excluded if published in any other language but English, Portuguese, Spanish, Italian and Croatian. After applying the language exclusion criteria, articles were screened by title and then by abstract. Articles were included if their research considered construction workers exposed to heat stress.

3 RESULTS

The identification process resulted with 1142 articles. After excluding 301 articles published in other language but English, Portuguese, Spanish, Italian and Croatian, 841 articles were left to screen. By screening article titles and excluding repeated articles, additional 303 articles were excluded, leaving 538 more to screen. After excluding by abstract and including articles which were related to construction workers exposure to heat, it remained 15 articles for screening in full text version. By screening the references of those 15 articles, another 5 were included as were found to be in accordance with the objective of this review. Therefore, in total, 20 articles were fully screened. From those 20, two were excluded as they were not research articles. Finally, 18 articles were included in this review. In table 1 are illustrated included studies which considerate at least one lifestyle factor.

Table 1. Included studies and considerate participant's lifestyle factors

Reference	1 Cigarette Smoker	2 Alcohol	3 Coffee	4 Tea	5 Water	6 Food	7 Spicy food	8 Sleeping hours	9 Physical condition	10 Body fat
1. (Islam and Khennane 2012)	x	x			x	x		x		
2. (Rowlinson and Jia 2014)	x									
3. (Jia, Rowlinson, and Ciccarelli 2016)	x									
4. (Inaba, Kurokawa, and Mirbod 2009)	x	x	x		x			x		
5. (A. P. C. Chan, Wong, et al. 2012)	x	x			x			x		x
6. (A. P. C. Chan, Yi, et al. 2012)					x					x
7. (A. P. Chan et al. 2013)	x	x			x					x
8. (Yi et al. 2017)		x	x		x				x	
9. (Farshad, Montazer, and Monazzam 2015)				x	x					
10. (Morioka, Miyai, and Miyashita 2006)					x					
11. (Dutta et al. 2015)	x		x							
12. (Maiti 2008)									x	

*x = variable considered by the study; **MC = Phase of the Menstrual Cycle

4 DISCUSSION

All included lifestyle factors were studied separately in order to comprehend the real influence of each one of them. Although some of them have a minor influence on the results of the studies, some of them have greater influence and should be taken into consideration in further works evaluating human heat exposure. As each factor has its particularity, and the number of factors is high, many were not included in this review such as: environmental variables, metabolic heat production, clothing, acclimation, illness history and medications taking.

The present review restrict to ten lifestyle factors influencing heat stress response in exposed humans: smoking cigarettes, alcohol, coffee, tea, water and food intake, spicy food intake, sleeping hours, human physical condition and body fat. Six of the included articles didn't consider neither one lifestyle factor (Pérez-Alonso et al. 2011; Sett and Sahu 2014; Hajizadeh, Golbabaei, and Monazzam 2014; Yang and Chan 2017; Heus and Kistemaker 1998; Mairiaux and Malchaire 1985).

4.1 Smoking cigarettes

Cigarette smoking was considered by 7 included studies (A. P. C. Chan, Wong, et al. 2012; Rowlinson and Jia 2014; Islam and Khennane 2012; Jia, Rowlinson, and Ciccarelli 2016; Inaba, Kurokawa, and Mirbod 2009; A. P. Chan et al. 2013; Dutta et al. 2015). This factor was found to be important to consider as it includes a number of health effects, among others, respiratory and circulatory impairment to the heart, brain and legs (Brodish 1998), smokers having significantly lower (27%) aerobic power than nonsmokers, and higher respiratory exchange ratio (Raven, P.B., Drinkwater, B.L., Horvath, S.M., Ruhling, R.D., Gliner, J.A., Sutton, J.C.,Bolduan, N.W. 1974). Further on, as smoker's sympathetic nervous system is already activated, their sweat onset would occur sooner for their higher sweat sensitivity, they would have a greater thermoregulatory response, and therefore enhancing evaporative heat loss to allow for cooling (Taylor and Machado-Moreira 2013). Nevertheless, it is important to notice that vasodilatory and sweating response (thermoregulation) was not found neither to be hindered nor enhanced in young light smoker's (Anderson 2012).

4.2 Alcohol consumption

Drinking alcohol was considered by 5 included studies (Yi et al. 2017; A. P. C. Chan, Wong, et al. 2012; Islam and Khennane 2012; Inaba, Kurokawa, and Mirbod 2009; A. P. Chan et al. 2013). The effect of alcohol on thermoregulatory response depends on dosage. It cause conduit artery vasodilatation, increased skin blood flow, chest sweat rate, sympathetic nerve firing rate, heart rate, and cardiac output (Spaak et al. 2008). After alcohol intake, the core temperature was found to decrease and the whole body thermal sensation to increase, while changing just a little after water intake (Yoda et al. 2005). Therefore, alcohol intake should be considered prior to conducting experiments.

4.3 Coffee and Tea consumption

Coffee intake was considered by 3 included studies (Yi et al. 2017; Inaba, Kurokawa, and Mirbod 2009; Dutta et al. 2015). Caffeine is a common element of most diets and it may dramatically alter nutrient metabolism by increasing turnover of free fatty acids and elevating the level of sympathetic nervous activity as well as possibly decreasing muscle insulin sensitivity. Furthermore, it was found that with increased caffeine-increase endurance (Graham 2001). The effect of caffeine depends on dosage, environmental conditions and intensity of exercise.

Caffeine ingestion of 5 and 10mg/kg was found not to have a significant influence on oxygen uptake, heart rate, core temperature, sweat rate and water deficit and heat storage in the body (Falk et al. 1990; Dunagan, Greenleaf, and Cisar 1998). Nevertheless, this factor would have a greater influence with higher dosage intake, longer and more intensive exercise in more extreme environmental conditions (Dunagan, Greenleaf, and Cisar 1998).

Tea was considered only by 1 study (Farshad, Montazer, and Monazzam 2015). It is important to control both coffee and tea for its diuretic effect.

4.4 Water consumption

Drinking water was considered by 8 studies (Morioka, Miyai, and Miyashita 2006; A. P. Chan et al. 2013; A. P. C. Chan, Yi, et al. 2012; Inaba, Kurokawa, and Mirbod 2009; Islam and Khennane 2012; A. P. C. Chan, Wong, et al. 2012; Yi et al. 2017; Farshad, Montazer, and Monazzam 2015). Poor water and electrolytes intake with great lost through sweating, can result in plasma volume reduction, posing further challenge to the cardiovascular homeostasis (Havenith 2005). Dehydration results in increased physiological strain as measured by core temperature and heart rate, decreased blood volume, reducing central venous pressure and cardiac output (Tribuzi and Laurindo 2016). The water intake should be primarily considered before the start of the trial, and then continuously monitored during the experiment.

4.5 Food and Spicy food consumption

Only one study controlled food intake (Islam and Khennane 2012), while neither one considered spicy food intake. Following ingestion of a meal and depending on its composition, the HR and cardiac output would increase, and BP would decrease (Kearney, Cowley, and Macdonald 1995).

4.6 Sleeping hours

Sleeping hours were considered by 3 studies (A. P. C. Chan, Wong, et al. 2012; Islam and Khennane 2012; Inaba, Kurokawa, and Mirbod 2009). Previous studies found that sleep deprivation alters thermoregulatory response, resulting in reduced core temperature (Landis et al. 1998), therefore it is important to consider this factor in future studies.

4.7 Physical condition and body fat

Physical condition was considered by 2 (Yi et al. 2017; Maiti 2008) and body fat by 3 studies (A. P. Chan et al. 2013; A. P. C. Chan, Wong, et al. 2012; A. P. C. Chan, Yi, et al. 2012). Exercise in heat stress was found to have differences as great as 0.9°C between subjects with different fitness levels (Selkirk et al. 2001). Further on, endurance-trained individuals and those with high level of aerobic fitness were found to tolerate higher core temperatures. High body fat participants were found to have significantly higher body mass compared with low-fat participants. Therefore, as high body fat have lower heat capacity compared with blood, water, bone and skeletal muscle (Selkirk et al. 2001), the core body temperature of high body fat participants was found to be higher (being unable to dissipate excessive body heat).

The limitations of this review lay in considering only studies encountered through the CAPES search. More studies and relevant information might be encountered by including new key-words from present studies.

5 CONCLUSIONS

Most of the included studies considered six basic factors: air temperature, radiant temperature, relative humidity, air movement, metabolic heat production and clothing. Among additional lifestyle, cigarette smoking and water consumption were the most considered factors, while tea and food consumption, and physical condition, were poorly considered. Future studies considering heat exposure should select their participants considering their lifestyle factors: smoking cigarettes, alcohol, coffee, tea, water and food intake, spicy food intake, sleeping hours, human physical condition and body fat. Not considering mentioned factors can pose a risk of bias and mislead in the interpretation of the results.

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